WVDOH PORTLAND CEMENT CONCRETE INSPECTOR AND TECHNICIAN

PROGRAMMED INSTRUCTION MANUAL

CONCRETE INSPECTOR AND TECHNICIAN TRAINING PROGRAM

PROGRAMMED INSTRUCTION MANUAL

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STUDY GUIDE

STUDY GUIDE FOR

PORTLAND CEMENT CONCRETE (PCC) TECHNICIAN

STUDY GUIDE

1.0 Introduction

1.1 Purpose

The purpose of this study guide is to serve as a review and reference for personnel who are preparing to take the examination for certification as a PCC Technician.

The questions and problems contained in this study guide should be typical of those that will be given in the exam.

In addition to questions and problems, the study guide contains a course study outline and a list of pertinent references.

1.2 Scope

Specific areas covered on the exam are:

Fundamentals: Basic questions on materials and tools of the trade.

Sampling and Testing: Questions relating to sampling and the frequency of sampling, required tests, and test procedures.

Control and Inspection: Questions pertaining to plant control methods and operations required to maintain a uniform product. Problems relating to batch weight and moisture.

Mix Proportioning and Adjustment: Problems and questions pertaining to the design of concrete mixtures and the control and adjustment of proportions.

2.0 Study Outline

Study Outline in Portland cement concrete

The following is a general study outline covering the areas required for certification.

STUDY OUTLINE FOR
PORTLAND CEMENT CONCRETE
TECHNICIAN CERTIFICATION

WEST VIRGINIA DIVISION OF HIGHWAYS

Fundamentals

A. Basic Concepts
   1. Components
      a. Paste
      b. Aggregates

B. Characteristics of Quality Concrete
   1. Hardened Concrete
      a. Durability
      b. Strength
      c. Impermeability
      d. Wearability
      e. Economy
   2. Fresh Concrete
      a. Workability
      b. Finishability

C. Producing Quality Concrete
   1. Quality of Paste
      a. Cement Content
      b. Water Content
      c. Entrained Air
   2. Quality of Aggregate
      a. Wear Resistance
      b. Durability
      c. Strength
      d. Shape and Texture
      e. Grading
      f. Maximum Size
      g. Impurities
   3. Mixing Operations
      a. Time
      b. Speed
      c. Load
      d. Condition of Mixer
   4. Placing
   5. Finishing
   6. Curing

Sampling and Testing

A. Sampling
   1. Cement
   2. Water
   3. Admixtures
   4. Aggregates
      a. Fine
      b. Coarse
   5. Concrete
      a. Central-Mix
      b. Truck-Mix

B. Testing
   1. Aggregates
      a. Gradation
      b. Moisture
      c. Unit Weight
      d. Specific Gravity
   2. Concrete
      a. Consistency
         (1.) Slump
      b. Entrained Air
         (1.) Pressure Method
         (2.) Volumetric Method
      c. Unit Weight and Yield
      d. Strength
      e. Speedy Moisture Tester

Control and Inspection

A. Materials Handling and Storage
   1. Aggregates
      a. Types and Sizes
      b. Preparation for Storage
      c. Stockpiling
      d. Bin Charging
   2. Cement
      a. Type Identification
      b. Conveying and Storage
   3. Water
      a. Source (Quality and Quantity)
      b. Temperature
   4. Admixtures
      a. Types
      b. Precautions
   5. Extreme Weather Operations

B. Batching
  1. Systems
  2. Batchers
  3. Scales
     a. Accuracy Tests
  4. Recorders

C. Mixing and Transportation
  1. Central-Mix
     a. Mixing Units
     b. Hauling Units
  2. Truck-Mix
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<u>Mix Proportioning and Adjustment</u>

A. Determining Proportions of Materials
  1. Specification Requirements
     a. Slump Range
     b. Standard Size of Aggregate
     c. Minimum Cement Factor
     d. Maximum Water Content
     e. Range of Entrained Air Content
     f. Strength
  2. Material Relations
     a. Water Requirement: Aggregate Size
     b. Air content: Aggregate Size
     c. Coarse Aggregate: Fine Aggregate
  3. Adjustment of Proportions
     a. Air Content
     b. Slump
     c. Yield
  4. Statistics
     a. Average
     b. Standard Deviation
     c. Normal Distribution
     d. Basic Statistical Applications to Quality Assurance

3.0 Examination

3.1 General

An examination will be given in one part covering all of the previously described areas.

3.2 Examining Period

The examining period for Technicians will consist of 3 hours. Registration will begin 30 minutes prior to the start of the exam.

Registration:	7:30 AM
PCC Technician Test:	8:00 AM -11:00 AM

3.3 Types of Questions

The examination will be made up of multiple-choice questions. The exam will be "open book".

4.0 Sample Questions and Problems

The following questions and problems should be typical of those that will be given on the exam. It is recommended that candidates work the following sample test as a practice exercise. Answers can be found on pages 27-29 of this study guide.

4.1 Typical Fundamental Questions

1. Paste requirement is generally related to the surface area of aggregate in which of the following manners?

    (a) Increases as surface area of aggregate increases

    (b) Decrease as surface area of aggregate increases

    (c) Is not affected by variation of surface area of aggregate

2. Over-sanding has what effect on the surface area of the aggregate in a concrete mix?

   (a) Increase surface area

   (b) Decrease surface area

   (c) Has no effect on surface area

3. If the specific gravity of an aggregate increases, the weight required per cubic yard to maintain the same volume will?

   (a) Increase

   (b) Decrease

   (c) Remain the same

4. Which of the following constitutes the greatest volume in a batch of concrete?

   (a) Water

   (b) Aggregates

   (c) Cement

5. The primary purpose for entraining air in concrete is to cause which of the following effects?

   (a) Improve workability

   (b) Reduce mix water requirement

   (c) Improve durability

6. Reducing the maximum size of a concrete aggregate will have what effect upon the mix water requirements to develop a particular consistency?

   (a) Decrease mix water requirements

   (b) Increase mix water requirements

   (c) Have no effect upon mix water requirements

7. Compressive strength of concrete depends mostly on which of the following?

   (a) Sand-aggregate ratio

   (b) Type of cement

   (c) Water-cement ratio

8. Additional water, beyond what is required to hydrate the cement, is used primarily for which of the following reasons?

   (a) Durability

   (b) Workability

   (c) Density

9. A job calls for 80 bags of cement. This means it requires how many pounds of cement?

   (a) 376 lbs.

   (b) 7520 lbs.

   (c) 940 lbs.

10. All other things being constant, an increase in temperature generally causes entrained air to vary in which of the following ways?

   (a) No change

   (b) Decrease

   (c) Increase

4.2 Typical Sampling and Testing Questions

1. During the initial curing period of 24 ± 8 hours after molding, concrete cylinders shall be stored within which of the following temperature ranges?

    (a) 70 °F to 76 °F

    (b) 70 °F to 72 °F

    (c) 60 °F to 80 °F

2. Portland cement concrete mixed in a stationary mixer and transported in a truck mixer should be sampled in which of the following ways?

    (a) At two or more regularly spaced intervals during discharge of the middle portion of the batch

    (b) From the initial discharge from the truck

    (c) From at least five locations around the load of concrete as deposited on the grade

3. In accordance with AASHTO test procedures, slump is measured by determining the vertical difference between the top of the mold and

    (a) The original center of the base of the specimen

    (b) The highest portion of the specimen

    (c) The displaced original center of the top surface of the specimen

4. During the operation of determining the air content of fresh concrete by the volumetric method, the sides of the bowl were not tapped after each layer was rodded. This could cause the instrument reading to be which of the following?

    (a) The actual air content of the concrete

    (b) Greater than the actual air content of the concrete

    (c) Less than the actual air content of the concrete

5. Which of the following procedures would best indicate the compressive strength of concrete when making test specimens in the field?

   (a) Make one cylinder from each portion of the sample

   (b) Make each cylinder separately from the composite sample

   (c) Make a set of cylinders at the same time from the composite sample

6. After securing a concrete sample, all tests must be started within how many minutes?

   (a) 5 minutes

   (b) 10 minutes

   (c) 15 minutes

7. Why is coarse aggregate one of the most difficult concrete components to sample?

   (a) Because of its tendency to segregate

   (b) The sample is too heavy to carry

   (c) It's very difficult to obtain a sample that will pass the gradation test

8. In accordance with AASHTO, a coarse aggregate test sample portion for gradation having a nominal maximum size of 1½ inches would have to weigh at least?

   (a) 10,000 grams

   (b) 15,000 grams

   (c) 20,000 grams

9. Samples of aggregate should be representative. From which of the following sampling points would you most likely obtain a representative sample?

   (a) Storage bin

   (b) Conveyor belt to storage bin

   (c) Stockpile

10. Determine the Bulk Specific Gravity (SSD Basis) of aggregate using the following information.

Oven-dry weight	4375 grams
Saturated surface dry weight in air	4900 grams
Weight of saturated sample in water	3045 grams

(a) 2.29

(b) 2.36

(c) 2.64

11. Given the following information, determine the unit weight of the concrete in pounds per cubic foot.

Weight of container	10 lbs.
Weight of concrete in container	70 lbs.
Correction factor on bucket	2.050

(a) 123.0 lb/ft^3

(b) 140.0 lb/ft^3

(c) 143.5 lb/ft^3

12. While conducting a slump test:

(a) The cone should be filled in ________ layers

(b) Each layer should be of equal ___________

(c) Each layer should be rodded ________ times

(d) Each layer of the cone should be tapped ________ times with the rubber mallet

13. In sampling concrete from truck mixers, the sample for making cylinders should be taken from?

(a) The beginning of the discharge

(b) The end of the discharge

(c) At two or more regularly spaced intervals during the discharge of the middle portion of the batch

14. A sample of sand weighing 350 grams is sieved over the standard sieves for fine aggregate for concrete. The sample shows the following cumulative weights retained on the various sieves. Calculate the fineness modulus of the sand.

Sieve	Cumulative Wt. Retained (grams)
3/8 inch	0
No. 4	7
No. 8	35
No. 16	105
No. 30	210
No. 50	315
No. 100	343
Pan	350

Answer: ___________

15. A sample of coarse aggregate, when sieved over the listed sieves, shows the following weights retained on each sieve. Calculate total percent passing for each sieve. (Record results to nearest whole percentage point)

Sieve	Weight Retained	Percent Passing
1 ½ inch	0	(a)
1 inch	5	(b)
¾ inch	15	(c)
½ inch	35	(d)
3/8 inch	13	(e)
No. 4	4	(f)
No. 8	2	(g)
Pan	1	(h)

4.3 Typical Control and Inspection Questions

1. The batch weight of sand is 1,230 lbs. If a 1,000-gram sample from the batch weighs 946.6 grams when oven dried, how many pounds of dry sand are there in the batch?

   Approximately: _______________ lbs.

2. In a given concrete mix, the coarse and fine aggregate make up 75% of the volume. The specific gravity of the fine aggregate is 2.70, and the specific gravity of the coarse aggregate is 2.30. If the sand-aggregate ratio were 0.40, how many tons of fine aggregate would be required to produce 1,000 cubic yards of concrete?

   (a) 468 tons

   (b) 682 tons

   (c) 1024 tons

3. An air-entraining admixture dispenser is observed to be dispensing variable quantities of admixture. This would have what affect on the concrete?

   (a) Slump would be uniform

   (b) Slump would be variable

   (c) Slump would be unchanged

4. Unit weight tests indicate that a mix is over-yielding. How will this affect the cement factor?

   (a) Cement factor will not be affected

   (b) Cement factor will be increased

   (c) Cement factor will be decreased

5. A concrete mix weighing 4500 lbs. contains 5 bags of cement. With a unit weight of 150 lb/ft^3, what is the actual cement factor in lb/yd^3?

   (a) 423

   (b) 522

   (c) 556

6. Determine the percentage of free moisture in the following sample of sand.

Dry weight of sand	500 grams
Saturated surface dry weight	540 grams
Wet weight of sand	560 grams

(a) 3.7%

(b) 8.0%

(c) 12.0%

7. In calibrating the water meter on a paving mixer, 50 gallons of water were metered and its weight determined. If the water weight reading was 399.84 lbs., what is the percent error of the meter?

(a) + 3.5%

(b) - 4.0%

(c) + 4.2%

8. Batch weights are as follows:

Cement	600 lbs.
Water	300 lbs.
Fine Aggregate	1,400 lbs.
Coarse Aggregate	1,900 lbs.
Air	6% by volume
Unit Weight Test	140.0 lb/ft^3

How many cubic feet of concrete has this batch produced?

Answer: ____________ ft^3

9. A concrete mix calls for 1,000 pounds of sand in a saturated surface dry condition (SSD). The sand as delivered to the job site contains 5% moisture above SSD. What is the correct batch weight?

(a) 1050 lbs.

(b) 1100 lbs.

(c) 1150 lbs.

10. Determine the percentage of free moisture contained in the following sample of fine aggregate using the “Speedy Moisture Tester”.

Wet Weight of F.A.	26.0 grams
% Absorption in F.A.	2.7%
Speedy Dial Reading	9.3%

(a) 6.6%

(b) 7.4%

(c) 8.7%

4.4 Typical Mix Proportioning and Adjustment Questions

The PCA publication Design and Control of Concrete Mixtures will be used for problems in this section. Concrete mix design calculations are based on procedures set forth in the American Concrete Institute Publication ACI 211.1-5. The following general relationships and properties may also be applicable:

1) One gallon of water weighs 8.33 lbs.
2) Unit weight of water = 62.4 lb/ft^3
3) A bag of cement weighs 94 lbs.

4) Water-cement ratio = $\dfrac{\text{weight of water}}{\text{weight of cement}}$

5) Sand-aggregate ratio = $\dfrac{\text{Volume of Sand}}{\text{Volume of Sand + Volume of Coarse Aggregate}}$

6) Absolute Volume = $\dfrac{\text{Wt. Of Material}}{\text{Specific Gravity of Material x Unit Wt. of Water}}$

7) Specific Gravity of Cement is 3.15

8) A change in mix water of 10 pounds will change the slump by 1 inch.

9) When the air content is to be adjusted and it is desired that the adjustment should not affect the slump of the concrete, the mix water should be increased (if air is removed) or decreased (if air is added) by 5 pounds for each 1% change in air content.

10) Abbreviations:

gal = gallon	g = gram
ft = foot	lb. = pound
ft^2 = square foot	in. = inch
ft^3 = cubic foot	psi = pounds per square in.
yd = yard	SSD = saturated surface dry
yd^2 = square yard	w/c = water-cement ratio
yd^3 = cubic yard	S/A = Sand-aggregate ratio
cwt = hundred-weight	°F = degree Fahrenheit
FA = fine aggregate	CA = coarse aggregate
max. = maximum	MNS = nominal maximum size
min. = minimum	FM = fineness modulus
ABS = absorption	sp. gr. = specific gravity

1. Using the following information, design a concrete mix to produce a cubic yard of air-entrained concrete.

Cement Factor	564 lb/yd^3
Target Slump	3 inches
Target Air Content	6%
Nominal Maximum Size of CA	1" crushed stone
Specific Gravity of CA (SSD)	2.60
Specific Gravity of FA (SSD)	2.70
Dry-Rodded Unit Wt. of CA	105 lb/ft^3
Fineness Modulus	2.60
CA Absorption	2.0%

(a) Considering the NMS of the CA and the target slump, what is the weight of water to be used in this mix?

______________ lb.

(b) What is the volume of water to be used in the mix?

______________ ft^3

(c) What is the weight of cement to be used?

______________ lb.

(d) What is the volume of cement to be used?

______________ ft^3

(e) Considering the NMS of the CA and the FM of the FA, calculate the volume of the dry CA for this mix.

______________ ft^3

(f) Calculate the weight of the dry CA for this mix.

______________ lb.

(g) Calculate the weight of the CA (SSD) to be used.

______________ lb.

(h) Calculate the volume of the CA (SSD) to be used.

______________ ft^3

(i) What is the volume of the air in the mix?

_____________ ft^3

(j) What is the volume of FA (SSD) to be used?

_____________ ft^3

(k) What is the weight of the FA (SSD) to be used?

_____________ lb.

2. Using the following information, determine the weight of cement to be used.

a) CA No. 67 crushed stone
b) Target Slump = 2 inches
c) Target Air Content = 6%
d) Design 28-day compressive strength = 4000 psi

Weight of Cement = ____________ lbs.

3. The following was used to produce a 3 cubic yard batch of concrete:

Cement	1692 lbs.
Water	570 lbs.
Air	6%
Coarse Aggregate	6225 lbs.
Fine Aggregate	3300 lbs.

Field tests indicate that the unit weight of the concrete is 143.6 lb/ft^3

a) What is the actual batch volume? ___________ ft^3

b) Is the batch volume over or under the designed volume? ______________

4. Proportions for a concrete mix design call for 1,300 lbs. of FA in a SSD condition. The design was based on a sp. gr. (SSD) of 2.60. A re-check shows that the sp. gr. should have been 2.70. What is the corrected batch weight (SSD) of the FA?

____________ lb.

5. The following mix is designed to produce one cubic yard of concrete with a 1 1/2 inch slump.

Cement	525 lbs.	2.67 ft^3
Water	31 gal.	4.13 ft^3
CA (2.68 sp. gr.)	1690 lbs.	10.11 ft^3
FA (2.64 sp. gr.)	1440 lbs.	8.74 ft^3
Air	5%	1.35 ft^3

In order to place concrete for a heavily reinforced pier, the slump must be changed to 4 inches. Adjust the mix to obtain a 4-inch slump and maintain the original water-cement ratio. Make any volume adjustments in the fine aggregate (to maintain the one cubic yard volume).
Answer the following after the adjustments:

a) w/c = __________

b) Weight of cement = __________ lbs.

c) Weight of water = __________ lbs.

d) Weight of FA = __________ lbs.

6. Given:

Cement	564 lbs.		2.87 ft^3
Water	30 gal.		4.01 ft^3
CA (sp. gr. 2.70)	2118 lbs.		12.60 ft^3
Air	6%		1.62 ft^3
FA (sp. gr. 2.65)	975 lbs.		5.90 ft^3
		Total	27.00 ft^3

The above concrete mix is over-sanded. The finish can be improved by reducing the sand-aggregate ratio to 0.30. It is desired to maintain the yield of 27.00 cubic feet, and only coarse and fine aggregate quantities will be adjusted. Make this adjustment and show new batch weights and volumes.

Coarse Aggregate __________ lbs. __________ ft^3

Fine Aggregate __________ lbs. __________ ft^3

7. Using the following information, design a concrete mix to produce one cubic yard.

a)	Cement factor	564 lbs.
b)	Water-cement ratio	0.50
c)	Air content	6.0%
d)	Coarse aggregate (SSD)	1551 lbs.
e)	Specific gravity of CA (SSD)	2.56
f)	Specific gravity of FA (SSD)	2.54
g)	Target slump	3 in.

Field test results show that the slump is consistently 5 inches, air is 9%, and the unit weight is 135.4 lb/ft^3. Adjust the mix to meet the design requirements. Make any volume changes that are necessary in the aggregate portion of the mix. Maintain the design sand-aggregate ratio.

I. Sand-aggregate ratio: __________

II. New weight of water: __________ lbs.

III. New weight of coarse aggregate: __________ lbs.

IV. New weight of fine aggregate: __________ lbs.

8. Using the following information, design a concrete mix to produce one cubic yard.

Cement factor	564 lbs. minimum
Slump	1 to 2 inches
Air content	7.0%
Coarse Aggregate	NMS = 1 inch crushed stone
	dry rodded unit wt. = 110 lb/ft^3
	specific gravity = 2.68
	absorption = 0.68%
Fine aggregate	fineness modulus = 2.70
	specific gravity = 2.56

Enter the batch weights and volumes below:

Water:	__________ lbs.	__________ ft^3
Cement:	__________ lbs.	__________ ft^3
Air:	__________ lbs.	__________ ft^3
Coarse Aggregate (SSD):	__________ lbs.	__________ ft^3
Fine aggregate (SSD):	__________ lbs.	__________ ft^3

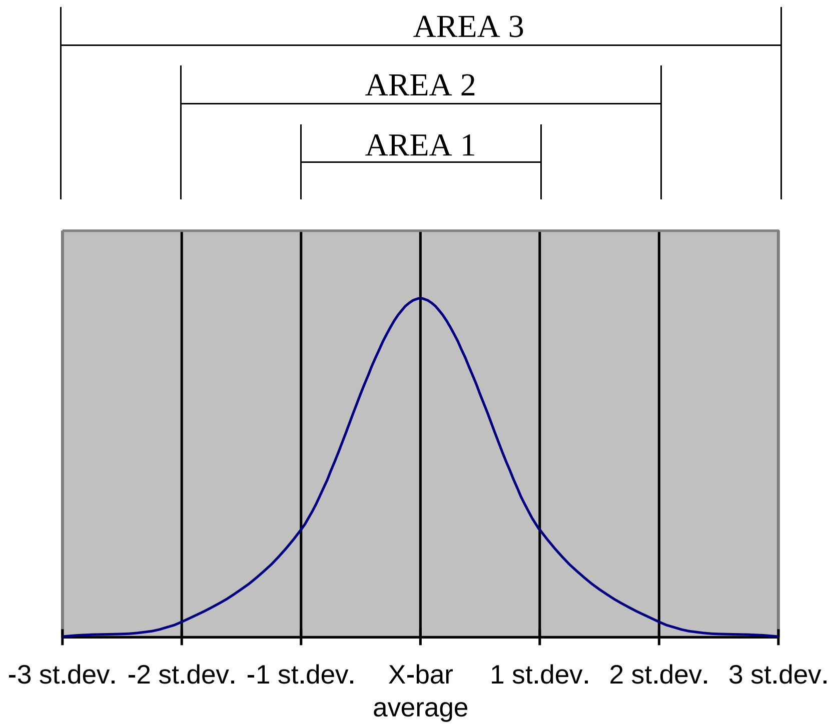
9. Design an air-entrained concrete mix that will meet the following requirements.

A) Cement factor = 6 ½ bags minimum
B) 28-day compressive strength = 4000 psi
C) Slump = 3 ½ inches
D) The concrete will be exposed to moderate conditions
E) AASHTO No. 67 coarse aggregate
  Crushed stone
  Dry rodded unit weight = 110 lb/ft^3
  Specific gravity (SSD) = 2.70
  Absorption = 1.8%
F) Fine Aggregate
  Fineness modulus = 2.70
  Specific gravity (SSD) = 2.60

Enter the batch weights and volumes below:

Water:	__________ lbs.	__________ ft^3
Cement:	__________ lbs.	__________ ft^3
Air:	__________ %	__________ ft^3
Coarse Aggregate (SSD):	__________ lbs.	__________ ft^3
Fine aggregate (SSD):	__________ lbs.	__________ ft^3

10. A standard normal distribution curve can be divided into certain defined areas.



σ = Standard Deviation (st. dev.)

$\overline{X}$ = Average

10.1 What percentage of the total area under a standard normal distribution curve lies between plus one standard deviation and minus one standard deviation?

(a) 33.33%

(b) 68.26%

(c) 72.67%

10.2 What percentage of the total area lies between plus two standard deviations and minus two standard deviations?

(a) 95.44%

(b) 90.76%

(c) 99.67%

11. What is the equation for standard deviation?

(a)

$$\sigma = \frac{\sum\left(X - \overline{X}\right)}{N - 1}$$

(b)

$$\sigma = \sqrt{\frac{\sum\left(X - \overline{X}\right)}{\left(N - 1\right)}}$$

(c)

$$\sigma = \sqrt{\frac{\sum\left(X - \overline{X}\right)^2}{\left(N - 1\right)}}$$

12. What is the average and standard deviation of the following compressive strength (psi) values?

4300	3730
4125	4000
3940	4110
4516	4200
3503	4450

(a) 4087.4, 311.56

(b) 4087.4, 295.57

(c) 4541.5, 311.56

13. Using the results of problem 12, what percent of the material represented by the data could be expected to have strength values in excess of 3,500 psi? (Use the table on the next page)

(a) 85.63%

(b) 96.99%

(c) 100%

Cumulative Areas Under the Standard Normal Distribution

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998

5.0 References

Knowledge of the following directives and memoranda is essential to the proper performance of a certified technician in the field during the production of specification concrete for the Division of Highways. These memoranda and others relating to the quality control of Portland cement concrete should be maintained in a current status and carefully reviewed at frequent intervals.

5.1 Informational Memorandum

IM-18	Plant and Equipment Inspection Stickers

5.2 Material Procedures

MP 106.03.50	General Information Guide for Quality Assurance Testing
MP 601.03.50	Guide for Quality Control and Acceptance Requirements for Portland Cement Concrete
MP 601.03.51	Standard Method for Determination of the Total Solids in Portland Cement Concrete
MP 601.03.52	Procedure Guidelines for Maintaining Control Charts for Portland Cement Concrete
MP 601.04.20	Curing Concrete Test Specimens in the Field
MP 601.04.21	Use of the Maturity Method for the Estimation of Concrete Strength on WVDOH Projects
MP 700.00.01	Sampling and Testing Material at the Source
MP 700.00.06	Aggregate Sampling Procedures
MP 700.00.30	Certification of Batch Scales and Calibration of Standard Test Weights
MP 701.01.10	Portland Cement Mill Certification
MP 702.00.20	Determining Free Moisture in Fine Aggregate using a 20 gram or 26 gram Capacity "Speedy Moisture Tester"
MP 707.04.10	Guide for Approval of Pozzolanic Additives
MP 711.03.23	Mix Design of Portland Cement Concrete
MP 711.03.26	Maintaining Specified Level of Strength in Portland Cement Concrete
MP 711.03.31	Development and Use of the Equation for Predicting Potential Strength of Portland Cement Concrete
MP 712.30.20	Capping Concrete Cylinders
MP 715.07.20	Standard Method of Test for Determining the Quality of Water Used with Hydraulic Cement

5.3 Trade Publications

Design and Control of Concrete Mixtures (15^{th} Edition)
– Portland Cement Association

Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete
- American Concrete Institute 211.1
May be obtained from:
American Concrete Institute
38800 Country Club Drive
Farmington Hills, Michigan 48331
Telephone # (248) 848-3800

5.4 Specifications

West Virginia Standard Specifications may be obtained online at:
http://www.transportation.wv.gov/highways/contractadmin/specifications/Pages/default.aspx
or from:
West Virginia Division of Highways
1900 Kanawha Blvd. East
Building 5, Room 722
Charleston, WV 25305
Telephone # (304) 558-9786
Fax # (304) 558-3132

Standard Specifications for Transportation Materials and Methods of Sampling and Testing – Parts 1A, 1B, 2A, and 2B
- The American Association of State Highway and Transportation Officials (AASHTO)
May be obtained from:
American Association of State Highway and Transportation Officials
444 North Capitol Street, N.W.
Washington, D.C. 20001
Telephone # 1(800) 231-3475

5.5 Manuals

West Virginia Division of Highways Construction Manual
May be obtained from:
West Virginia Division of Highways
1900 Kanawha Blvd. East
Building 5, Room 722
Charleston, WV 25305
Telephone # (304) 558-9786
Fax # (304) 558-3132

6.0 Answers to Sample Questions

6.1 Fundamentals (Section 4.1)

1. (a)
2. (a)
3. (a)
4. (b)
5. (c)
6. (b)
7. (c)
8. (b)
9. (b)
10. (b)

6.2 Sampling and Testing (Section 4.2)

1. (c)
2. (a)
3. (c)
4. (b)
5. (c)
6. (c)
7. (a)
8. (b)
9. (b)
10. (c)
11. (c)
12. (a) Three (b) Volume (c) 25 (d) Zero
13. (c)
14. 2.90
15. (a)100 (b)93 (c)73 (d)26 (e)9 (f)4 (g)1 (h)0

6.3 Control and Inspection (Section 4.3)

1. 1164
2. (b)
3. (b)
4. (c)
5. (a)
6. (a)
7. (c)
8. 30
9. (a)
10. (b)

6.4 Mix Proportioning and Adjustment (Section 4.4)

1. (a) 295 (g) 1995
   (b) 4.73 (h) 12.30
   (c) 564 (i) 1.62
   (d) 2.87 (j) 5.48
   (e) 18.63 (k) 923
   (f) 1956

2. 583

3. a) 82.1
   b) Over-yield (3.04 yd^3 > 3.00 yd^3)

4. 1350

5. a) 0.49
   b) 578
   c) 283.23
   d) 1329.42

6.

Coarse Aggregate	2182 lbs.	12.95 ft^3
Fine Aggregate	918 lbs.	5.55 ft^3

7. I. 0.46
   II. 277
   III. 1594
   IV. 1349

8.

Water:	270 lbs.	4.33 ft^3
Cement:	564 lbs.	2.87 ft^3
Air:	0 lbs.	1.89 ft^3
Coarse Aggregate (SSD):	2033 lbs.	12.16 ft^3
Fine aggregate (SSD):	919 lbs.	5.75 ft^3

9.	Water:	305 lbs.	4.89 ft^3
	Cement:	635 lbs.	3.23 ft^3
	Air:	5.0 %	1.35 ft^3
	Coarse Aggregate (SSD):	1905 lbs.	11.31 ft^3
	Fine aggregate (SSD):	1009 lbs.	6.22 ft^3

10.1 (b)

10.2 (a)

11. (c)

12. (a)

13. (b) see solution below:

$$Z = \frac{\left(\overline{X} - f'_c\right)}{\sigma} = \frac{(4087.4 - 3500)}{311.56} = 1.89$$

From the Table on page 24, the number that corresponds to a Z score of 1.89 is 0.9706 or 97.06%.

CHAPTER 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

This booklet has been prepared to assist you in learning the basic theory associated with the subjects leading to training as a Portland Cement Concrete (PCC) Inspector and a PCC Technician.

The PCC Inspector should be familiar with processes at the batch plant. The PCC Inspector's primary responsibility, though, is the inspection of concrete at the job site, and the sampling and testing of concrete. **It is a requirement that anyone who samples or tests concrete for acceptance be certified as a PCC Inspector.** The PCC Inspector may be a WVDOH employee, a Contractor employee, or a Consultant employee. Regardless of whom the PCC Inspector works for, if the results of any sample or test performed on concrete are to be used for acceptance, the sampler or tester must be a certified PCC Inspector. Besides being qualified to sample and test concrete, the PCC Inspector must know about good concreting practices (placing, curing, finishing, etc.) and must be familiar with the WVDOH Standard Specifications.

The PCC Technician must possess a more detailed knowledge of concrete and concreting practices than the PCC Inspector. The WVDOH Standard Specifications require that the Contractor maintain at least one certified PCC Technician who shall direct all field inspection, sampling, and testing necessary to determine the various properties of the concrete and maintain these properties within the specification limits. **Even though the PCC Technician is qualified to direct these activities, he or she is not qualified to sample or test concrete for acceptance (only the PCC Inspector is qualified to do this).** The PCC Technician must have extensive knowledge about plant processes and control (aggregate sampling and testing, concrete mix designs and adjustments, quality control, statistics, etc.), field sampling and testing, general concrete knowledge, and good concrete inspection practices.

It is intended that you study each chapter or section of this booklet prior to the formal class period on that section.

Each chapter has been prepared to correspond to the major subjects that will be covered. This material will be supplemented by filmed test procedures, hands-on testing (PCC Inspector only), and formal lecture. This will make up the initial phase of the training you will receive. This material will help you prepare for the written exam (both PCC Inspector and Technician) and the practical exam (PCC Inspector only).

The test for the **PCC Inspector** consists of two parts. The first part is a 100 question written exam (three hours long). The second part is a practical (hands-on) exam.

The 100 question written exam for the PCC Inspector will be an "open-book" test. It will consist of questions about the five tests that will be performed in the practical exam. There will also be questions about the WVDOH Standard Specifications, concrete batch plants, aggregate sampling and testing, and general quality control/quality assurance questions.

In the practical exam, you will be required to actually perform five different tests on a batch of concrete. These tests include the slump test, cylinder fabrication, determining the air content of concrete by the Type B pressure meter, determining the air content of concrete by the volumetric method (roll-o-meter), and determination of the unit weight and yield of concrete. All of this testing will be hands-on (you will actually perform the tests). You will need to do some calculations to determine the unit weight and yield of the concrete, though. You will not be permitted to use notes, pre-prepared worksheets, or take any material (other than a calculator) in the practical exam (it is closed book).

Everyone who desires to be certified as a PCC Inspector must first pass the written exam before they are eligible to take the practical exam. Once you pass the written exam, you are eligible to take the practical exam. Once you pass the practical exam, you will be certified as a WVDOH PCC Inspector.

The PCC Inspector written exam is scheduled twice a year (usually sometime between January and April). A minimum score of 70% is required to pass the written exam. The practical exam will be offered twice this year. The test location will be at MCS&T Division in Charleston, WV. Each one of the five individual tests that make up the practical exam must be performed completely correct in order to pass the practical exam. If you do not pass all five individual test portions of the practical exam on your first attempt, you will need to re-take all five individual test portions of the practical exam on your second attempt (including the portions that you passed on your first attempt). Once you pass the written exam, you have twelve-months from the date that you passed the written exam to pass the practical exam. If you do not pass the practical exam within this twelve-month period, you must re-take the written exam in order to become certified. See the following two pages for the regulations concerning the PCC Inspector practical exam.

PORTLAND CEMENT CONRETE INSPECTOR PRACTICAL EXAMINATION

Tests to be performed and regulations for completion of the Portland Cement Concrete Inspector Certification Program practical examination are as follows:

During the examination, you will be required to perform each test procedure in accordance with the appropriate test method required by the standard specifications. All equipment and testing apparatus will be supplied at the testing facility. You will not need to bring any materials with you for the practical exam. **It is a closed book practical exam, and no pre-printed forms, notes, or any other material may be used or reviewed once (any portion of) the exam has been started.**

The examiner is not permitted to answer any questions or otherwise assist you (either verbally or physically) in any means during the exam. Once you begin a test procedure, the examiner will not stop you even if you make a disqualifying error, nor will the examiner express anything resembling approval or disapproval.

If at any time before the test is completed and a result is given to the examiner, you realize that an error has been made, you may tell the examiner that you have made an error, and you will be allowed to start the test over with no penalty. However, once you give a result to the examiner, you have completed that test and no longer have the option to start the test over. If you realize that a mistake has been made after a result has been given to the examiner, it is too late to start over. The option to start a test over is available only once for each test procedure.

If any test procedure is not performed correctly, a failing score will be given. If you do not initially pass all portions of the exam, you will need to re-take the entire practical exam (all five individual tests). You may not re-take the practical exam until the next scheduled practical exam (i.e.: you may not re-take the exam the next day, etc.). If you do not pass the practical exam within twelve months from the date that you passed the written exam, you must re-take the written exam and the practical exam.

A candidate for certification must demonstrate the correct test procedures for all of the tests listed below.

1. AASHTO T 152 – Air Content of Freshly Mixed Concrete by the Pressure Method (Type B Meter)
2. AASHTO T 196 – Air Content of Freshly Mixed Concrete by the Volumetric Method
3. AASHTO T 119 – Slump of Hydraulic Cement Concrete
4. AASHTO T 121 – Unit Weight and Yield of Concrete (Yield Must be Calculated)
5. AASHTO T 23 – Making and Curing Concrete Test Specimens in the Field

The **PCC Technician** test is a written test consisting of one part. The test questions will cover fundamentals of concrete and aggregates, sampling and testing of concrete and aggregates, control and inspection of concrete and aggregates, and concrete mix proportioning and adjustment. The test will be a 3-hour "open-book" test and will consist of 80 multiple choice questions. A minimum score of 70% is required to pass the test.

PORTLAND CEMENT CONCRETE (PCC)

THE MAN-MADE STONE

As the title reads, we are going to be studying about a man-made stone. When we consider this man-made stone for a moment, we ask how is concrete made? We start with stone, sand, and clay. Then we fuse them together, grind them to a fine powder, and the result is cement. We then add water and more stone to this cement. After a short period of time, we have one big stone – a man made stone – concrete. There is no other construction product used in which man merely rearranges and reshapes a natural product into a usable and controllable product. This new product resembles the original form (from stone to a stone-like mass), and it has the qualities and form that we desire. To produce concrete with the qualities we desire we must know three things. These are:

1. What are the desirable qualities?
2. How do we build these qualities into concrete?
3. How can we check the concrete to ensure that the desired qualities are actually in the concrete?

The answer to these questions must be preceded by an understanding of what Portland cement concrete is. Concrete is made up of two components, paste and aggregates. The paste portion of concrete consists of cement, water, and very small air voids. The paste portion generally makes up 25 to 40% of the total volume of the concrete.

The aggregate includes both coarse aggregate and fine aggregate. The aggregates are used primarily as a filler material and as such, occupy from 60 to 75% of the total volume of the concrete.

In concrete that is properly designed and mixed, each particle of the aggregate, regardless of size, is completely surrounded by paste. All of the space between the aggregate particles needs to be filled with paste. It should be readily apparent that if the aggregates are suspended in the paste portion of the concrete, the quality of the concrete is largely dependent upon the quality of the paste.

The paste is also the part of the concrete that we can readily alter to change and control the properties we desire in the concrete. We can, of course, also influence some of the properties of the concrete by altering the aggregates.

First, however, we will consider the paste portion.

The quality of the paste portion is greatly dependent upon the ratio of water to cement that is used. The cementing properties of the paste are achieved through a chemical reaction between the cement and water. This reaction is called hydration. The amount of water required for hydration of cement is considerably lower than the amount of water required to make a workable concrete mix. As the amount of water is increased (beyond the amount necessary for hydration), the paste becomes thinner and the strength of the paste is lowered.

In freshly mixed plastic concrete, all of the granular solids, including cement, are temporarily suspended in water (with the individual particles being separated by thin layers of water). This separation of the particles, and lubricating effect of the water layers, makes the mix plastic and workable (or formable).

Thus, we must establish a point where the water content is high enough to provide workability of the material (to form it into the shape we desire) and still maintain the strength of the paste at the desired level.

All paste contains some air. Air voids aid the paste in making the concrete mix workable and plastic. The air voids assist in fixing the degree of separation of the aggregate particles in the paste.

The actual degree of separation of the aggregate particles determines the amount of settlement. In undisturbed, newly placed concrete, the solids slowly settle through the water. This settlement of the solids will generally result in a thin layer of water on the surface of the concrete. This process, resulting in visible water on the surface of the concrete, is known as bleeding. If the aggregate particles were originally well separated by the paste, settlement is stopped when the solid particles in the paste come together.

Air voids in the paste can affect the rate of settlement. The air voids tend to assist in holding the particles in suspension until the hydration process takes place and the solids are cemented together.

As previously stated, the quality of the aggregates also has an influence on the quality of the concrete. Generally speaking, if an aggregate consists of clean, hard, strong, and durable particles (that are free from chemicals and coatings of clay or other fine materials), it will be a suitable aggregate to use in Portland cement concrete.

Now that we know what concrete is, what are the desirable properties that we should look for in a concrete mix?

These properties can be controlled during the design of the concrete mix, the batching of the concrete mix, and during the handling of the concrete mix while it is in its plastic state. After the concrete hardens, we cannot alter its properties.

Although freshly mixed concrete is only temporarily plastic, its properties are important because they affect the quality of the hardened concrete.

The proportioning of materials in the plastic concrete has a great affect on the properties of the hardened concrete. The plastic mix must have the proper water content, the proper air content, and the proper cement content. These are all properties that can be determined in the plastic concrete and used to forecast some of the desirable properties of the hardened concrete.

There is one single term used to describe the desirable properties in plastic concrete. This term is workability.

Concrete in the plastic state is not really usable to us, though. The properties that we look for in the plastic concrete must have some affect on the hardened concrete.

There are certain properties of the hardened concrete that are extremely important. These properties are the result of control of certain properties prior to and during the plastic state.

One of the most important characteristics of hardened concrete is durability. The most destructive force to concrete is freezing and thawing while the concrete is wet or moist. As the water in hardened concrete (that is saturated) freezes, it expands. This expansion creates forces within the concrete. When the forces become great enough, the concrete will crack.

Entrained air in concrete can help to lessen these forces. The entrained air voids allow an area in which some of this expansion will take place. Because some of the expansion takes place in these voids, there is less expansion (and therefore less force) left to crack the concrete.

Concrete with a low water to cement ratio (w/c) that also has a sufficient amount of entrained air will generally remain intact under any exposure condition for extended periods of time.

The strength of hardened concrete is also affected by the properties of plastic concrete. The water-cement ratio (w/c) is the greatest contributor to the strength of the concrete. The curing (care it is given during and after the plastic state) of the concrete also greatly affects the concrete.

We now know that the qualities that we consider desirable in concrete have to be designed into the mix, controlled during the batching operation, and measured in the plastic concrete.

The remainder of this manual will assist you in determining the proper procedures to use in determining the qualities of Portland cement concrete.

CHAPTER 2

PRODUCTION

SECTION 2.1

PRODUCTION FACILITIES

There are three general categories for batching facilities. Any approved batching facility may produce concrete for any size or type of job. However, the size of the job, the type of structure and the required production rate generally limits the type of production facility that can be used.

The three categories into which a plant can be placed and description of each is as follows:

Category 1 - Manual Batching

A manual batching facility is distinguished by the fact that all batching operations are manually activated and controlled. All aggregate sizes are generally cumulatively weighed on the same scale. The cement is weighed separately and generally batched separately from the aggregates. This type of facility is limited in the amount of production possible.

Category 2 - Semi Automatic (Cumulative) Batching

A semi - automatic facility is just what its name implies. The operator manually sets the predetermined batch weights and then activates the batching sequence. The aggregates are automatically weighed into a cumulative weigh hopper. The cement is automatically weighed to the pre - set amount, on a separate scale. The admixture dispenser is most generally automatically controlled.

After all of the materials have been weighed into their respective weigh hoppers, the operator manually discharges the batch into the truck or mixer. This type of facility provides for good control of the accuracy of batching materials as well as providing for a higher production rate than that possible with most manual operations.

Category 3 - Fully-Automatic (Individual) Batching

A fully automatic facility is also just what its name implies. Pre-tested batch proportions are set into the controls. These proportions would generally be those required to produce one (1) cubic yard of concrete. The operator selects the size batch desired and activates the batching.

The amount of each size aggregate needed to produce the selected batch size is automatically weighed into individual hoppers. While this weighing is taking place, the proper amount of cement is also being weighed into a separate hopper. These materials are systematically released into the truck or mixer along with the required water and admixtures.

When the total required materials for the batch are discharged into the truck or mixer, the cycle will automatically repeat the weighing of a batch of materials.

This type of facility is generally equipped with recording devices to record the batch weights or amounts, as well as certain characteristics of the materials, the concrete mixture, and the production process.

A fully automatic facility will generally provide the maximum in production rate as well as provide for good control over the uniformity of the end product - the concrete.

As was pointed out earlier, the type of construction, size of the job, and the required production rate will generally determine the type and size of the plant facility that will be used. This does not mean, however, that each facility for each specific need will be completely different from other facilities for other needs. Even though the control of the batching sequence may differ markedly, there are certain features of each type of plant that are relatively the same. For example, the batching facilities for a truck mix plant operation can be categorized as any of the three facilities just discussed.

All plant facilities, whether manual, semi-automatic or fully automatic, will include aggregate stockpiles, aggregate storage bins, weigh hoppers and scales, cement storage facilities, admixture dispensers, and a water-measuring device. The requirements for handling, storing, controlling, and measuring of the batch materials are the same for each plant. Plants differ only in that some are newer, some are fancier, some are automatically controlled, some are small, and some are large.

All batching facilities service some type of concrete mixer. There are three general types of mixers used for highway construction. They are:

1. Paver-mixer
2. Central mixer
3. Truck mixer.

A paver mixer is generally serviced by a dry batch plant. This plant would include aggregate storage bins, cement storage tanks, weigh hoppers, and scales. The aggregates and cement are batched separately into special compartment trucks.

A central mixer is generally serviced by a batching facility that is automated to some degree. The aggregates, cement, water, and admixtures are generally charged simultaneously into the mixer. This plant would include aggregate storage bins, cement storage tanks, weigh hoppers and scale, storage and dispensing facilities for the admixtures, and storage and dispensing facilities for water.

A truck mixer is serviced by facilities that vary from manual to fully automatic. This facility would generally include the same equipment as the facility servicing a central mixer, and in some instances, the facility may be the same for both types of mixers.

When concrete is completely mixed in a truck mixer, uniformity requirements (in Annex A of AASHTO M157) must be met within 70 to 100 revolutions of the drum at mixing speed. This ensures that the truck mixer has the capability of adequately (and uniformly) mixing concrete.

When concrete is delivered in a truck mixer, no water shall be added after the initial introduction of mixing water except when, upon arrival at the job site, the slump of the concrete is less than that specified. This water shall be added in accordance with section 601.7 of the specifications. Discharge of the concrete shall be completed either within the time limits set forth in section 601.7 or within 300 revolutions of the drum (whichever comes first). The start of the time limit or the number of revolutions of the drum begins immediately after the introduction cement to the aggregates.

Even though it would be desirable for a plant to be equipped to charge a truck mixer with all of the material necessary to complete the mix, there are circumstances that will require other arrangements. If the concrete is to be placed a considerable distance from the batch plant, a cement silo may be installed at the job site and the cement added at the job site, thus eliminating the problems associated with prolonged hauling. It may also be desirable to add only a portion of water at the plant and allow a small amount to be added at the job site to modify the consistency.

Our discussion this far has been purposely limited to production facilities in which the materials are batched by weight. Equipment that uses volumetric batching and continuous mixing, a "mobile mixer", is also available to produce concrete.

Side or End Dump Trucks

The side dump is open at the top and discharges from the side directly into the spreader box of a paving train by tilting the entire bed of the truck to the side. These trucks are generally equipped with a vibrator.

There are two types of end dump trucks. One type of end dump truck is very similar to the normal type of dump truck. The top of this truck is open and the truck discharges from the back (full width) onto a spreader or directly on the base. This truck bed should be both smooth inside and tightly constructed to prevent leaking of the concrete.

A second type of end dump truck dumps from the end through a chute similar to that used on a standard truck mixer.

Under no circumstances should concrete be hauled in a truck that has a bed constructed of aluminum.

The truck mixer is not only a mixer vehicle but may be used to transport central mixed concrete. There are no special requirements placed on a truck mixer to allow transporting of central mixed concrete. If the truck mixer meets the requirements for mixing concrete, it is also suitable for transporting concrete.

SECTION 2.2

MATERIALS HANDLING AND STORAGE

PORTLAND CEMENT

Much of the Portland cement now being used is shipped in bulk by rail or truck to concrete producers or directly to the construction site, where it is quickly unloaded by automatic equipment into silos or hoppers for storage. Cement is also available in paper bags.

All cement must be handled and stored so that it is kept perfectly dry. If cement that has been exposed to dampness is used in concrete, the concrete will not develop its full strength.

Temperature of Portland cement is extremely important. If hot cement is used in a batch, <u>extra mixing water</u> would be required to make the concrete workable and the <u>concrete may be weakened</u>. In some cases, concrete in which hot cement is used may stiffen rapidly and develop what is called a <u>flash set</u>. Such concrete cannot be finished easily.

Cement is shipped from approved sources to certified batch plants. Cement shipped in bags should be treated with extreme care. A bag may be rejected if it is torn or punctured. If hard lumps are felt in a corner or any portion of a bag, the bag shall be rejected.

Bags of cement should be randomly weighed to ensure the proper weight per bag. For our purposes, we will use the traditional U.S. standard weight and consider the weight of one bag of cement to be 94 pounds. Cement used in bag form should be stored in such a way that the oldest cement will be used first.

Cement bags will retain their moisture barrier effectiveness if the following rules are observed:

1. Cement should never be stacked against an outside wall.
2. Cement should never be stacked on a floor that is in contact with the ground.
3. Cement should be stacked as close together as possible to prevent circulation of air between the bags. The bags of cement should be covered with a tarp or some material that would prevent the intrusion of dampness.

REMEMBER THAT CEMENT WILL RETAIN ITS QUALITY INDEFINITELY IF IT DOES NOT COME INTO CONTACT WITH MOISTURE. IF IT IS ALLOWED TO ABSORB APPRECIABLE MOISTURE, IT WILL SET MORE SLOWLY AND ITS STRENGTH WILL BE REDUCED.

Cement for a small job is sometimes stored in a trailer type of truck. When cement is stored in this type of facility, it should be stored on a raised platform in the middle of the body of the truck. If the end or side of the truck is open, care must be taken to prevent the intrusion of moisture.

When cement has been stored a long period of time, the cement should be re-tested and considered on the basis of the new results.

Cement delivered to a batch plant in bulk is unloaded in many ways. The most common are with air pressure or with screws. The one general requirement of any means of transferring cement is that it be air tight to prevent the intrusion of moisture.

DIFFERENT BRANDS OF CEMENT OR THE SAME TYPE OF CEMENT FROM DIFFERENT MILLS SHALL BE STORED SEPARATELY.

AGGREGATE

Aggregate stockpiling and maintaining of the stockpiles is an asset to any producer that is interested in producing a quality concrete. Aggregates should be transported in sealed containers so as to prevent leakage of the finer materials. All aggregates of different sizes and different sources must be stockpiled separately. Aggregate stockpiles should be built and maintained in such a way that segregation can be minimized and separated so as not to have stockpiles intermingle or come in contact with harmful materials. The stockpile base is of the utmost importance. A proper base lessens the chance of contaminating the stockpiles. The best type of stockpile base is, naturally, a concrete pad. Wooden planks or stabilized aggregate may be used for the base. The ground (if it has been cleared of all vegetation) may be used as a base if there is at least one foot of aggregate on the ground at all times.

Stockpiles can be built in many ways. The following will provide you with some examples of stockpiling procedures:

Stockpile #1 - A proven method of stockpiling is to build the stockpile in uniform 3 feet layers. This can be easily accomplished with conveyor belts or with clamshell cranes. If a crane is used, the aggregate should be discharged onto the stockpile area from a maximum height of about 3 feet. The stockpile can be reclaimed with the clamshell crane, or with a front-end loader, depending on the size and depth of the stockpile.

Stockpile #2 - Stockpiles can be built with a clamshell crane or conveyor belt in small cones. The smaller the cone, the better the end result will be, uniformity. When a supplier is limited to a very small area, the general practice is to build a large cone shaped stockpile. Stockpiles built in this fashion usually have a great degree of segregation. Sometimes, good aggregates are rejected because of poor stockpiling procedures. If the stockpile is built in small cone shaped piles, which are approximately 3 feet in depth and reclaimed with a front-end loader, the resulting uniformity will be good but not as good as if built with the procedure outlined for stockpile Number 1.

Stockpile #3 - If a conveyor belt continually discharges in one position, the end result will be a tent shaped pile of aggregates. You may expect a great degree of segregation from a stockpile built in this manner and reclaimed with a clamshell bucket. If a stockpile is built in this manner and reclaimed with a front-end loader, the segregation will be minimized. A front-end loader can be used to mix the aggregate as it is being loaded.

Stockpile #4 - Stockpiles are sometimes built with front-end loaders. This procedure can offer, as an end result, good uniformity but not as good as the procedure described for Stockpile Number 1. The fact that makes this procedure so widely acceptable is that the normal front-end loader is versatile and has an effective height of about 8 feet. If a stockpile is built with a front-end loader, it would be desirable to reclaim the stockpile in as many layers as it was built.

The equipment coming into contact with the stockpile must also be considered. All equipment, such as a front-end loader, used around the stockpile should have rubber tires. Equipment used on the stockpile must have rubber tires.

The condition of the aggregates plays a big part in the ease of stockpiling. For example, sand or fine aggregate in a dry condition is almost impossible to handle with any type of equipment. Coarse aggregate, when it is dry, has a tendency to dust, causing pockets of excessive amounts of fines.

More times than not, aggregates are washed and drained at the quarry prior to shipment to a concrete plant. Aggregates that are washed as they are stockpiled should be permitted to drain for approximately 12 hours. If they are permitted to dry, they shall be sprinkled approximately 12 hours prior to being used as part of a concrete mix. The control of any kind of concrete mix is better when the aggregates are maintained in a saturated surface dry condition.

The following are some questions that you may ask yourself as you are observing a stockpile being built:

1. Is this method of stockpiling acceptable?
2. Is the equipment used around the stockpiles acceptable?
3. Is this stockpile going to be separated from other stockpiles of other sources and types of aggregates?
4. Is contamination or degradation prevented or minimized during the handling?
5. Is the stockpile in at least a saturated surface dry condition that would prevent dusting or degradation?

Aggregate handling from stockpiles to holding bins should involve the same precautions as those observed during the building of a stockpile. Improper handling can cause a great degree of segregation as the holding bins are being charged. If the aggregates are dropped vertically into a cone shaped pile, then the aggregates will become segregated. An attempt should be made to restrict the flow as the aggregates are charged into the holding bins. A baffle and a rock ladder are the best-proven methods for distributing the aggregates evenly in a holding bin. The aggregate bins should be kept as nearly full as possible to prevent segregation and breakage of the aggregates. Aggregate holding bins should be separated in such a way that a run-over between two bins will be prevented.

WATER

Water may be measured into a batch by either weight or volume. The water may be added at the batch plant and/or at the job site. Water quality is quite easily controlled because the source is generally approved periodically in accordance with the sampling frequency outlined in the Construction Manual. Once the quality has been established, the inspection would consist of calibration of the equipment and control of quantity.

The water lines that allow the passage of the water from the meter to the truck should be checked quite frequently. A water leak that occurs on the intake side of the water meter is of little concern since it has no effect on the measuring of the water, but it is always a good policy to prevent leakage in any place.

When water is weighed, the weigh hopper and the line leading from the hopper shall be free of leaks.

ADMIXTURES

Admixtures include all materials other than Portland cement, water, and aggregates that are added to a concrete mix. Admixtures include additives that can influence concrete in many ways. Concrete should be workable, finishable, strong, durable, watertight, and wear resistant. These qualities can usually be obtained without the use of admixtures; however, some of these qualities can be more easily obtained by using admixtures.

Admixtures can influence fresh concrete by inducing special properties such as delayed setting time, accelerated setting time, increased workability, etc.

The handling and storage of admixtures is easily accomplished. The admixture should not be allowed to freeze, and it should be agitated to prevent settlement. Liquid admixtures are generally shipped in large drums. Powder type admixtures are generally shipped in cardboard drums or boxes. The admixtures should be stored in the shipping container since it is generally designed to prevent the intrusion of moisture. Care should be exercised to prevent the admixture from being contaminated with foreign substances during use.

SECTION 2.3

PLANT INSPECTION

A concrete production plant should be a facility that can combine suitable ingredients into a thorough blend, and deliver it without incident. Prerequisites for this operation are qualified personnel, and the availability of proper equipment that is well maintained. Concrete producers desiring to supply concrete for the State Division of Highways normally contact qualified personnel at the District to establish a working relationship and to discuss in detail the requirements necessary.

For our discussion we will assume that this is the first visit to a plant that is going to be inspected. The supplier should furnish the Division a list of all materials and the source of each, such as:

1. Coarse aggregate
2. Fine aggregate
3. Cement
4. Water
5. Admixtures

The sources of all materials should be compared to the lists of approved sources distributed by the Materials Control, Soils and Testing (MCS&T) Division of the Division of Highways. A list of approved aggregate sources containing names and locations of all aggregate sources where the quality requirements of the aggregate have already been approved is periodically issued.

If the source of the aggregates is not on this approved list, then appropriate arrangements should be made to determine if the source material would comply with specifications.

The cement source should be compared to the list of approved cement sources, which is also distributed by the MCS&T Division. If the source is found on this list it is qualified to provide, with some restrictions, Type I cement for use on State projects.

A sample of the water should be taken and sent to the Materials Laboratories for test. As a general rule, water that is suitable for drinking will generally be suitable for use in concrete. The source of the water will dictate the sampling frequency. A water source that is an approved municipal water supply will not have to be sampled and tested. An untreated source of water will have to be sampled at least once every three months.

Admixtures are approved several different ways. The concrete producer must submit evidence based on tests made in a recognized laboratory, to show that the air-entraining admixture he intends to use meets the requirements of AASHTO designation M-154. AASHTO M-154 is a standardized procedure for acceptance or rejection of an air entraining admixture based on flexural and compressive strength tests and the resistance to freezing and thawing. (A recognized laboratory is any laboratory that is inspected regularly by the Cement and Concrete Reference Laboratory of the National Bureau of Standards.)

An exception to the above requirement would be when the supplier elects to use an air-entraining admixture that is manufactured by neutralizing vinsol resin with caustic soda. Acceptance of this type of admixture is based on a letter of certification submitted to the MCS&T Division for approval.

Also, if the supplier proposes to use an air-entraining admixture, which has been previously approved, he should submit a certification stating that the admixture is the same as that previously approved. If the admixture is essentially the same as one that has already been approved, except for minor differences in concentration, then a letter of certification may be submitted and approved on this basis.

There are optional test requirements for air entraining admixtures. At any time prior to or during construction the engineer may require that the admixture be further tested to determine its effect upon the strength of the concrete. This is done by comparing the strengths of concrete containing the air-entraining admixture to concrete without the admixture. The requirements for this test are described in Article 707.1.3 of the West Virginia Division of Highways Standard Specifications for Roads and Bridges.

Specifications allow the use of water-reducing admixtures (Types A & F) and water reducing set-retarding admixtures (Types D & G). Acceptance requirements consist of laboratory test reports showing conformance to the requirements of AASHTO M-194. The test reports must be complete in all respects reflecting data called for in Section 19 of AASHTO M-194.

In addition to the above, performance tests are required for final approval of an admixture in a concrete design. The AASHTO specification acknowledges that specific effects produced by chemical admixtures may vary with the properties of the other ingredients in the concrete. Therefore, our specifications dictate that no admixture covered by AASHTO M-194 (with some exceptions regarding plasticizers) shall be used until the concrete made with the ingredients proposed for use by the Contractor, including the admixture, is shown to meet the requirements of AASHTO M-194 for water reduction and compressive strength increase at ages 3, 7 and 28 days. The laboratory doing the concrete design for the Contractor normally accomplishes these performance tests.

The Division of Highways may elect to develop design mixes that are combinations of different aggregate sources and types with different sources of cement, and types, and use them for a comparative analysis basis for the acceptance of water-reducing retarders.

Also, when a supplier proposes to use an admixture that has been previously approved, he needs to submit a certification stating that the admixture is identical in composition with the sample that was used for the basis of the initial acceptance. If the admixture varies somewhat in composition to the original sample then a certificate would be required which states that the composition is essentially the same. We have established that all materials should be delivered to the plant site from approved sources or the material on hand should be approved prior to use.

INSPECTION OF HANDLING AND STORAGE OF MATERIALS

The handling and storage of all materials, and the inspection thereof should be approached from a practical standpoint. One of the vital requirements of quality assurance is the control of the batch plant operations and the possibility of foreseeing situations that could become unacceptable. Briefly, the usual routine duties of a batch plant inspector would include witnessing the weighing and measurement of all materials being batched and assuring himself/herself that these materials meet the applicable specifications. Prior to the start of a job the suppliers' personnel should be made aware of all quality control procedures, which are applicable to the handling and storage of the materials. The producer is responsible for the quality control of his product. One of the most critical items in the storage and handling of materials concerns how the aggregates are handled and stored. As previously discussed aggregate stockpile bases may be any one of the following:

1. Concrete pad
2. Wooden planks
3. Asphalt slab
4. Stabilized base
5. Earth or ground in which all vegetation has been removed.

A concrete slab is a preferred base for aggregates. The other types of bases listed above can be used but care must be exercised to prevent the base from becoming intermingled with the aggregates.

All aggregates that go into a concrete mix must be in a condition that is <u>at least</u> saturated surface dry (SSD). Therefore, the water system used for maintaining the aggregates in this condition would have to be checked and the acceptability determined.

The method of transferring aggregates from storage area to holding bin must be checked. The points to consider while observing the transfer operation are:

1. Are aggregates kept separate from all other aggregates?
2. Are aggregates permitted to become contaminated in any way?
3. Is every possibility considered to prevent segregation?

The inspection of cement as far as shipping, handling and storage are concerned is very simple. The cement may be identified by the bill of lading that must accompany each shipment. The information on the bill of lading should be compared with the current certified mill list to determine the approval status of the cement. The procedure for acceptance or rejection of cement is outlined in MP 701.01.10. The inspection of the cement storage facility consists of assuring that the facility is airtight and the cement is protected from dampness. The silo should be completely airtight, except for a ventilation pipe that prevents pressure build up. An escape hatch that can be unbolted and allow easy entrance to inspect the inner parts of the silo should be located at the top of the silo. The inspection of the inside of the silo assures that there is no build-up of hardened cement.

Cement left in storage for a considerable time should be checked to determine if there has been a build-up of hardened cement. Cement that has been left in storage for over 90 days must be re-tested before it is used.

The silo or storage facilities for cement should be equipped with some device that could provide agitation for easy and consistent flow of cement. This is generally accomplished with air jets, vibrator, or equipped with both. The cement weigh hopper should also be equipped with some type of agitation (this is generally accomplished with a vibrator). The weigh hopper must be sealed. This means that the area from the top of the weigh hopper to the bottom of the silo that feeds the weigh hopper must be completely enclosed. When this is accomplished, the weigh hopper must be vented to provide the escaping of air as the weigh hopper is being charged. While the weigh hopper is being charged there should be absolutely no dust from the cement escaping from the weigh hopper, except through the vents.

If the supplier is using cement by the sack, the same acceptance procedure for each shipment is used. The cement should come from an approved source that can be determined from the bill of lading. If cement is not from an approved source, required sampling must be done and samples sent to the MCS&T Division for test. The cement must not be used until the samples have been tested and show that they meet specification requirements. The inspection of approved, bagged cement is generally restricted to the storage thereof.

You should assure yourself that the area the cement will be stored in is free from all dampness. The sacks that arrive first should be the first ones used. The inspector should frequently, at random, check a sack of cement for the required weight.

WATER

The inspection of the water system shall include visual inspection of all connections from the water meter to where the water empties into the truck or mixer. If the water is weighed, the inspection for water leaks should be expanded to include the checking of the weigh hopper. The pipe from the bottom of the weigh hopper to the point of entry into any mix must be completely free of leaks.

ADMIXTURES

Probably the first thing in any inspector's mind when inspecting admixture dispensers is:

1. Are the admixture dispensers automatic?

According to paragraph 601.5.2.6 of the West Virginia Division of Highways Standard Specifications for Roads and Bridges, the admixture dispenser is required to be automatic. One good definition of automatic is: Any mechanical device that will dispense a predetermined amount of an admixture when manually or mechanically activated.

The inspection of admixtures will include:

1. Are admixtures prevented from freezing?
2. Are admixtures stirred frequently to prevent settlement of solids?

Up to this point the inspection has been conducted visually. Now, we must concern ourselves with the calibration of all equipment at the plant site. When we speak of calibration, it is in the terms of the ability of any measuring equipment, weighing equipment, mixing equipment and timing devices to perform within the specified tolerances. This calibration will be discussed in two parts. The first part of the discussion will deal with plants that use conventional weight type batching equipment. The second part will deal with inspection of volumetric batching equipment.

Simplified accuracy checks must be conducted on the batch scales during each week of production.

The supplier shall have all scales approved by the Division of Labor at least once a year. Also, outlined in MP-700.00.30 is the requirement that each batch plant doing business with the Highway Division have ten fifty-pound test weights that shall be certified by the West Virginia Division of Labor.

When the Division of Labor seals a scale, it means only that the scale was within certain limits or tolerances at the time it was checked. Dirt can collect on scale parts and cause incrustation, and cause the scale to weigh incorrectly; therefore, it is a requirement of the Division of Highways that all scales be checked weekly.

The ability to accurately weigh and batch the component materials is very important to the quality of concrete that is obtained as the finished product. Section 501.7 of the WVDOH standard specifications specifies procedures for batching and tolerances within which certain materials must be batched.

In accordance with the standard specifications, cement must be batched within a tolerance of one percent, and aggregates must be batched within a tolerance of two percent. Water may be measured either by volume or by weight. The accuracy of measuring the water shall be within a range of error not over one percent. All admixtures shall be measured into the mixer with an accuracy of three percent.

As outlined in the West Virginia Division of Highways Construction Manual, the scale should be given a complete accuracy check every six months, and the accuracy checked, using the simplified method, on a weekly basis. The procedures for conducting these accuracy checks can be found in paragraphs 708.1.4 and 708.1.5 of the Construction Manual.

We shall assume that the plant to be inspected is a new facility, therefore, the bins would have to be filled and left standing for a period of time in order to compensate for the settling and bending of the steel that may occur.

The procedure for checking the complete accuracy of a scale is relatively simple. The procedure is as follows:

STEP 1. Add ten fifty-pound test weights (totaling 500 lbs.). This is an actual weight. Record it in Column A, Line 1.

STEP 2. Record beam or dial reading in Column B, Line 1.

STEP 3. Remove test weights.

STEP 4. Add material until the beam or dial reading is same as Column B, Line 1.

STEP 5. Add the test weights; add this 500 pounds to the last actual weight determined (500) and record in Column A, Line 2.

STEP 6. Record beam or dial reading in Column B, Line 2.

STEP 7. Continue this procedure to maximum batching capacity. (NOTE: Tolerance will not increase beyond the tolerance applied at the point of ¼ capacity).

STEP 8. Column C is the difference between Column A and B.

STEP 9. Column D is allowable tolerance per NIST Handbook 44, Section 2.20, Table 6.

Use the worksheet on the following page and the information that has been included to complete the check of the accuracy of a cement scale.

BATCH SCALE COMPLETE ACCURACY CHECK

REQUIRED EVERY SIX MONTHS

PRODUCER:				DATE:	
LOCATION:					
MAKE OF SCALE:				DIVISION:	5 lbs.
TYPE: LOAD CELL		BEAM	DIAL X	CAPACITY:	8,000 lbs.
MATERIAL: CEMENT	X	AGGREGATE			
TEST CONDUCTED BY:					

CONDITION OF SCALES

Knife edges free from dirt and excessive wear?	YES	NO	N/A
Weigh hopper clean and hanging free?	YES	NO	
Scales zeroed and balanced?	YES	NO	

INSTRUCTIONS

1. Add ten 50 lb. test weights (totaling 500 lbs.) and record this Actual Weight in Column A, Line 1
2. Record the beam, dial, or load cell reading in Column B, Line 1
3. Remove the test weights
4. Add material until the beam, dial, or load cell reading is exactly the same as Column B, Line 1
5. Add the test weight: Add 500 lb. to the last actual weight determined (500 lbs.) and record in Column A, Line 2
6. Record beam, dial, or load cell reading in Column B, Line 2
7. Continue this procedure to maximum balance capacity*

**** Scales with load cells,***

Continue this procedure to 25% capacity

Then remove test weights, add material to 50% capacity, and add the test weights to determine error at this point

Then remove test weights, add material to 75% capacity, and add the test weights to determine error at this point

Then remove test weights, add material to full capacity, and add the test weights to determine error at this point

8. Column C is the difference between Columns A and B
9. Column D is Allowable Tolerance per NIST Handbook 44, Section 2.20, Table 6

LINE	ACTUAL WEIGHT "A"	SCALE READING "B"	ACTUAL ERROR "C"	ALLOWABLE ERROR "D"
1		508		
2		1000		
3		1495		
4		2005		
5		2498		
6		3000		
7		3502		
8		4007		
9		4497		
10		5000		
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				

REMARKS: ______________________________

____

SCALE MEETS SPECIFICATIONS? ***YES ________*** ***NO ________***

Excerpt from NIST Handbook 44 – 2015, "Specifications, Tolerances, and Other Requirements for Weighing and Measuring Devices" see Table 6 "Maintenance Tolerances"

Now that you have finished the scale check, answer the following

1. What is the actual weight in Column A. Line 7?

1.1 3500 lbs.

1.2 3470 lbs.

Turn to the next page for the answers.

1.1 RIGHT CHOICE. The actual weight of material is 3500 lbs. Each time the material was increased in the weigh hopper by 500 pounds.

LINE	ACTUAL WEIGHT COLUMN A	DIAL READING COLUMN B	ACTUAL ERROR COLUMN C	ALLOWABLE ERROR COLUMN D	LINE	ACTUAL WEIGHT COLUMN A	DIAL READING COLUMN B	ACTUAL ERROR COLUMN C	ALLOWABLE ERROR COLUMN D
1	500	508	+8	5	16				
2	1000	1000	0	5	17				
3	1500	1495	-5	5	18				
4	2000	2005	+5	5	19				
5	2500	2498	-2	5	20				
6	3000	3000	0	5	21				
7	3500	3502	+2	5	22				
8	4000	4007	+7	5	23				
9	4500	4497	-3	5	24				
10	5000	5000	0	5	25				
11					26				
12					27				
13					28				
14					29				
15					30				

1.2 NO. The actual weight of material is 3500 pounds. Each time material was added to the weigh hopper exactly 500 pounds was added.

The supplier may elect to have 12 fifty-pound weights instead of 10. Checking a scale, which has a 30,000-pound capacity, marked off in 30-pound gradations would be easy to check in 600-pound increments. If you check the scale using 500-pound increments you would have difficulty estimating the weight because the gradations would not allow you to read the weight at 500 pounds.

We know that in accordance with the Standard Specifications Section 109.1 and NIST Handbook 44, Section 2.20, Table 6 (see pg. 2-21) that we have a scale accuracy tolerance of five divisions per 500 divisions. If the scale's minimum division is 5 lb., then we know our allowable tolerance is 5 lbs. up to a load of 2500 lbs. The allowable tolerance determined at ¼ percent capacity (2,000 lbs. in this case) will be the allowable tolerance to full capacity. If we take the increments in which we had our greatest error, it would look something like this. In the 1500-pound range of the scale check we were in error 5 pounds. So checking our error (5 lbs.) against the allowable error which is 1 division (also 5 lbs.), our actual error is less than or equal to our allowable error and we have an acceptable situation.

Some scales, which have a capacity of only about 1000 or 1500 pounds, would be checked using small increments. To accomplish this, you would check the scale in fifty-pound increments or 100 pound increments at the very most. The tolerances regardless as to the scale capacity are the same.

REMEMBER, A SCALE NEED ONLY BE CHECKED THROUGHOUT ITS RANGE OF USE. THE SCALE CHECK SHOULD BE CONDUCTED TO THE CLOSEST 500-POUND INCREMENT ABOVE THE MAXIMUM BATCHING CAPACITY OF THE MATERIAL TO BE WEIGHED ON THE SCALE.

Now that we have completed the scale checks, we should check the calibration of the admixture dispensers. On our first trial run in calibrating the admixture dispenser, we can determine if the dispenser is automatic or manual. As we are calibrating the dispenser we can check the repeatability of the dispenser.

Assume that the meter we are calibrating is automatic and is controlled by a timing device. The admixture is measured into a stand tube that has a scale graduated in ounces. The results of the accuracy check are as follows:

SECONDS	TARGET AMOUNT	TEST NUMBER 1	TEST NUMBER 2
2	180 ml	270 ml	270 ml

It was observed at this point that the measuring device is off 90 ml in 180 ml. Plant management was advised that the measuring device is not within specifications as permitted by Division of Highways Standard Specifications, Section 501.7. These specifications allow a tolerance of plus or minus 3%. After one adjustment to the timing device and some measurement by the producer, the accuracy of the device was re-checked with the following results:

SECONDS	TARGET AMOUNT	TEST NUMBER 1	TEST NUMBER 2
2	180	180	180
4	510	510	510
6	840	840	840
8	1050	1050	1050
10	1320	1320	1320
12	1590	1590	1590
14	1860	1860	1860

We have established enough information to accept the admixture dispenser as complying with the specification tolerances. During the check of the admixture dispenser, we established more than the calibration of the meters; we also established that the dispenser can be set and the admixture consistently measured to this amount.

Timing devices should be checked frequently. One reason is that the temperature of an admixture can cause a difference in viscosity thereby causing the volume to be pumped to differ with temperature changes.

In the case of dispensers that are magnetically controlled, the calibration required is simply to assure yourself that the quantity in ml in the measure is completely dispensed into the mix.

We shall now concern ourselves with the calibration of the water-measuring device. The plant-measuring device is a water meter, which has a capacity of approximately 100 to 150 gallons per minute. Before starting the calibration of the water meter we should make sure that the piping within the plant does not leak. Our real concern for leaks is between the water meter and the point of entry into the concrete mix.

We know at this plant that the most water that will be added in one operation will be 150 gallons. We can begin by placing a large container positioned on a platform scale under the water discharge. If the container will not hold the 150 gallons, or the scale will not weigh 150 gallons of water, then we will have to weigh accumulative. By this we simply mean to set the water meter in the plant on 150 gallons and run through enough water to fill the container, and weighing and dumping this portion, then releasing more water in portions up to the 150 gallons.

By doing it this way we are still checking the 150-gallon point. We would not be checking the meter at 150 gallons if we set the 30-gallon mark and released it 5 times. We would be checking the 30-gallon mark 5 times. Listed below is the test data developed during the calibration check of the water meter:

Gallons	Theoretical Wt	Test 1	Test 2	Avg.	Error
30	250	249.6	250.4	250.0	0.0
60	500	496.0	501.2	497.4	2.6
90	750	750.0	750.0	750.0	0.0
120	1000	999.5	999.5	999.5	0.5
150	1250	1250.0	1250.0	1250.0	0.0

In the second line, we have our greatest error (which is 2.60 pounds). In accordance with paragraph 601.5.2.5 of the Standard Specifications we see that we are allowed a tolerance of 1%. One percent of the actual weight, 501.2 lbs., is 5 pounds. We have an acceptable situation because it is within the limits specified.

The calibration and accuracy checks discussed so far could be related to equipment in any type of batching facility.

Even though the mixing and delivery of concrete is accomplished in several different ways there are many items of inspection that all have in common. All mixers, for example, should be equipped with a manufacturer's data plate that shows the mixing speeds and mixing and agitating capacity.

The Supplier would be responsible for supplying a copy of the original drawings of the drum showing the blade dimensions. These blades would be considered not to comply with the specifications when there is evidence of wear in excess of ¾ inch. The measured height of the blades can be compared with the drawings to determine the amount of wear.

The point at which the wear would be equal to ¾ inch can be marked by drilling a small hole in the blade ¾ inch down from the original height of the blade.

Before the plant supplies concrete to a project, tests should be conducted to determine the uniformity of concrete produced by the specific mixer. Specific procedures for determining uniformity are set forth in the Standard Specifications and AASHTO M-157.

Uniformity tests are conducted to check the performance of a concrete mixer (stationary mixer or truck mixer). These tests will tell you whether or not a mixer is performing adequately. The amount of time that concrete must be mixed in a stationary mixer depends on how uniform the concrete is mixed in this mixer. Truck mixers that are used to completely mix concrete must meet uniformity requirements within 70 to 100 revolutions. If the truck mixer cannot meet uniformity requirements within 100 revolutions, it shall not to be used.

If the mixer is a truck mounted mixer which is equipped with a water measuring device the device must be checked for accuracy the same as the plant meter. This may easily be accomplished with the water meter that is already a part of standard operating equipment within each district. To do this we hook the meter up to the water system and have the person normally responsible for measuring the water to dispense the water in amounts we require for the calibration check.

The 1% tolerance, which was applicable to the plant-metering device, is also the allowable tolerance on accuracy of the truck's metering device.

A supplier doing business with the State is required by Standard Specifications to have a field laboratory that will meet the requirements of Section 501.5.1. A field laboratory at the plant can be described as the following:

1. A minimum working area of 26 feet in length by 6 feet in width.

1.1 Heat

1.2 Lights

1.3 Ventilation

1.4 Sinks

1.5 Water

1.6 Drainage

1.7 Electrical outlets

1.8 Work tables

1.9 Shelves and storage area for supplies

2. The following equipment should be a part of any field laboratory assigned to a batch Plant.

2.1 Hot plate, gas or electric

2.2 Large oven, gas or electric

2.3 Pressure air meter or roll-o-meter

2.4 Slump cone and rod

2.5 Unit weight container

2.6 Solution balance, 20 kilograms capacity, one-gram increments.

2.7 Balance, minimum capacity 1000 grams, 1/10 of a gram increment.

2.8 Platform scale, 100-gram capacity

2.9 Thermometers

2.10 Standard Gilson shaker (or equivalent) and Ro-tap shaker (or equivalent), both equipped with necessary screens to accommodate the job requirements.

2.11 Wire basket and container for weighing aggregates under water (for specific gravity and absorption)

2.12 Sample splitter for fine and coarse aggregates.

2.13 Equipment for determining the specific gravity of sand.

2.14 Speedy moisture kit (20 gram or 26 gram capacity).

2.15 All field labs should be equipped with miscellaneous items, which include:

2.15.1 Rubber mallets, large and small

2.15.2 Mason's trowel

2.15.3 Square pointed shovel

2.15.4 Small and large scoops

2.15.5 Heavy galvanized pan

2.15.6 Aggregate sample pans

2.15.7 Brushes

2.15.8 Flashlight

2.15.9 Glassware if necessary

2.15.10 Steel straight edge (50 mm by 450 mm)

This equipment should be checked to determine if it meets the requirements of applicable ASTM or AASHTO test procedures.

The supplier shall be responsible for sampling tools as required in MP 700.00.06. If the aggregates are to be sampled at the belt, then it is the responsibility of the supplier to furnish a set of templates that would allow rapid sampling of the aggregates. If the aggregates are to be sampled prior to entering the weigh hopper then the supplier should be responsible for providing a rack that would allow the passage of sampling receptacles through the flow or discharge of the aggregates.

SIMPLIFIED SCALE CHECK

Scale accuracy checks are to be conducted weekly. When these accuracy checks are performed they shall be documented in the diary and performed in accordance to the procedures outlined in Section 708.1.4 of the Construction Manual. Attached (pg.2-34) you will find a copy of the form used to record that test data. This form also contains step-by-step instructions for conducting the test.

Before starting the scale check we should check the condition of the scale and its batching capacity. First, the knife-edges should be clean and should not show excessive wear. Second, we should make sure that the weigh hopper is hanging free. Third, we should check the scale for zero balance. On the attached form you will see the three points to check under 1.0, "CONDITION OF SCALE".

Assume that all the points we checked above were answered with a yes and we know that the normal batching capacity of this scale is 14,000 pounds. The first step would be to place the test weights on the scale, and record the beam or dial reading in Column 1, Line A.

We know that the 10 - fifty pound test weights should total 500 pounds, so in Column 2, Line A, our calculated scale reading should be 500 pounds. For our example the beam or dial reading when the test weights were on the scale was 502 lbs. and this value is entered on Column 1, Line A.

Now add material to approximately 1/3 of the batching capacity, which in this case is 14,000 pounds. So 1/3 of 14,000 pounds is approximately 5,000 pounds. We now add material until the beam or dial reading is 5,000 pounds. Record this reading in Line B of Column 1.

Now remove the test weights. With the test weights off, the scale reading is 4,516 lbs. Record this reading on Line C of Column 1. We know that when the scale or dial reading was 5,000 pounds and we removed the test weights the calculated scale reading should have been 4,500, which we shall document in Line C of Column 2.

We decided earlier that 5,000 pounds was approximately 1/3 of the batching capacity of the scale. Now add another 1/3 of the batching capacity that will put us at the 2/3 point of our normal batching capacity. With 5,000 pounds already in the hopper, we now add another 5,000 pounds, which is a total of 10,000 pounds. Record this reading in Line D of Column 1.

We know we have 10,000 pounds on the beam or dial reading, we now add the 500 pounds in test weights and record beam or dial reading in Column 1, Line E. The reading after the test weights were added was 10,565 lbs.

We knew earlier that we had 10,000 pounds, which is 2/3 point, and we added an actual 500 pounds in test weights. This gives us a calculated scale reading of 10,500 pounds and is recorded in Column 2, Line E.

With 2/3 of the batching capacity now recorded on the scale we shall now add material until the full batching capacity has been exceeded, which in this case is 15,000 pounds. After material has been added, the beam or dial reading is 15,000 pounds. This reading is recorded in Line F, Column 1.

Now, remove the test weights. The reading after the weights were removed was 14,522 lbs.

We know that the beam or dial reading before the test weights were removed was 15,000 pounds, and by taking off the 500 pounds in test weights we have a calculated scale reading of 14,500 which is documented in Line G, Column 2.

Now, find the error in the scale readings by determining the difference between the calculated scale reading (Column 2) and the actual error (Column 3).

Column 3, Line A should be 2 pounds.

Column 3, Line C should be 16 pounds.

Column 3, Line E should be 65 pounds.

Column 3, Line G should be 22 pounds.

The allowable error of 1 division (20 lbs.) is recorded in Column 4.

By comparing Columns 3 and 4 you can determine if the scale is within the requirements of the standard specifications. As you probably already realized, the error at the 2/3 point exceeded the allowable error, therefore we have an unacceptable situation. The scale will require at this time, a complete calibration check.

BATCH SCALE SIMPLIFIED ACCURACY CHECK
REQUIRED WEEKLY

PRODUCER: ______________________________________ DATE: _________
LOCATION: ____
MAKE OF SCALE: ____
TYPE: ________ BEAM: _______ DIAL: _______ CAPACITY: _14,000___lbs.
MINIMUM GRADUATION: _________20____ lbs.
MATERIAL WEIGHED: Cement: ____________ Aggregate: ____X________
CONDUCTED BY: ____

1.0 CONDITION OF SCALE (YES) (NO)

- 1.1 Knife-edges free from dirt and excessive wear ____ ____
- 1.2 Weigh hopper clean and hanging free ____ ____
- 1.3 Scale zero balanced ____ ____

2.0 INSTRUCTIONS

- 2.1 Place test weights on scale. Record reading in Column 1, Line A
- 2.2 Record calculated scale reading in Column 2, Line A.
- 2.3 Add material to 1/3 batching capacity. Record reading in Column 1, Line B
- 2.4 Remove test weights. Record reading in Column 1, Line C
- 2.5 Record calculated scale reading in Column 2, Line C
- 2.6 Add material to 2/3 batching capacity. Record reading in Column 1, Line D
- 2.7 Add test weights to scale. Record reading in Column 1, Line E
- 2.8 Record calculated scale reading in Column 2, Line E
- 2.9 Add material to batching capacity. Record reading in Column 1, Line F
- 2.10 Remove test weights. Record reading in Column 1, Line G
- 2.11 Record calculated scale reading in Column 2, Line G
- 2.12 Column 3 is the difference between Columns 1 and 2
- 2.13 Allowable error from NIST Handbook 44, Section 2.20 Table 6 makes up Column 4

LINE	ACTUAL SCALE READING COLUMN 1	CALCULATED SCALE READING COLUMN 2	ACTUAL ERROR COLUMN 3	ALLOWABLE ERROR COLUMN 4
A	502	500	2	20
B	5000			
C	4516	4500	16	20
D	10000			
E	10565	10500	65	20
F	15000			
G	14522	14500	22	20

REMARKS: ____
IF THE ACTUAL ERROR (COLUMN 3) EXCEEDS THE ALLOWABLE ERROR (COLUMN 4), THEN A COMPLETE CALIBRATION SHOULD BE CONDUCTED IN ACCORDANCE WITH SECTION 708.1.4 OR 708.1.5 OF THE WVDOH CONSTRUCTION MANUAL

Volumetric Batching and Continuous Mixing

(Mobile Mixer)

An inspection of the mobile unit should include the following:

1) Vibrators on the cement and aggregate bins are in proper working order.
2) The main conveyor belt should have the proper tension (to prevent sagging and loss of material) and must be clean and free of holes.
3) Aggregate gate openings should be within proper operating range.
4) The cement bin should be clean, dry, and any hard cement removed.
5) Aerators on the cement bin should be operative and the vent should be open and clear.
6) The meter is operating properly.
7) Water system is in good condition.
8) The mixing area is free from excessive concrete buildup and the mixing auger shows no excessive wear.

In order to determine the mobile unit's ability to discharge materials in the proper amount required by the design, a material discharge check must be performed. To perform this check you must know the weight of cement, sand, coarse aggregate, and water required by the design.

<u>Equipment</u>

1. A scale to weigh the material discharged.
2. A container in which to catch the material discharged.
3. A sheet metal deflector to chute the material into the container.
4. A container to catch the water.
5. A stopwatch.

Procedure

1. Calculate from the mix design the cement-coarse aggregate, cement-sand and water-cement ratios.
2. All compartments should be clean and dry.
3. Load the cement bin only.
4. Start the conveyor belt and allow it to make one revolution so it will be coated with cement. Stop it.
5. Again start the conveyor and stopwatch simultaneously.
6. Catch cement discharged for a period of 20 seconds. Weigh the cement. Repeat this procedure two more times and calculate an average. This weight of cement will be used to calculate the cement-aggregate ratio later.
7. Empty and clean the cement bin and conveyor belt.
8. Load the coarse aggregate bin only.
9. Set the gate control at the setting for the concrete design being used.
10. Start the conveyor belt and allow some aggregate to be discharged from the machine. Stop it.
11. Start the conveyor again and the stopwatch simultaneously.
12. Catch the materials discharged for a period of 20 seconds and weigh the material. Repeat at least twice and calculate an average.
13. Calculate the cement-coarse aggregate ratio using the cement weight determined in step 6 and compare it to the ratio obtained from the design. If the ratio is incorrect, readjust the gate control. Repeat procedure until ratio is correct.
14. Empty and clean the coarse aggregate bin and belt.
15. Load the sand bin only. Repeat the above procedure until the cement-sand ratio is correct.
16. Empty and clean sand bin and belt.

17. Fill the water tank. Start the mobile unit and bring it to operating speed. Set the water dial for the mix design being used.

18. Open the water valve (mechanical units) manually and start the stopwatch simultaneously. On hydraulic units start the main conveyor and start the stopwatch. Catch the water for 20 seconds.

19. Repeat, at least twice. Calculate an average. Calculate the water-cement ratio and compare it to that ratio obtained from the mix design. If incorrect, readjust controls and repeat procedure until ratio is correct.

SECTION 2.4

A-BAR (Ā)

DEVELOPMENT AND USE OF Ā (A - BAR) FACTORS

Ā is a factor that characterizes the gradation of an aggregate. The size of this factor is very highly correlated with aggregate surface area. It affects such parameters as the mix water required for a given consistency (slump) of concrete. In West Virginia it is used as a control in concrete mix designs.

The calculation of Ā is straight forward and is completely described in **Materials Procedure (MP) 601.03.51; Standard Method for Determination of Ā of the Total Solids in Portland Cement Concrete**.

Solid components in Portland Cement Concrete (PCC) include coarse aggregate, fine aggregate, cement, and sometimes fly ash. An Ā gradation must be conducted on both the coarse and the fine aggregates. The following sieve sizes are used: 1 1/2 in. (37.5 mm), 3/4 in. (19.0 mm), 3/8 in. (9.5 mm), No. 4 (4.75 mm), No. 8 (2.36 mm), No. 16 (1.18 mm), No. 30 (600 µm), No. 50 (300 µm), No. 100 (150 µm), and No. 200 (75 µm). When we look at the sizes and types of aggregates used in PCC, we can see that a combination gradation is not necessary. An example of a coarse aggregate size used for PCC is an AASHTO No. 67. As can be seen from the specifications for No. 67 (Table 703.4 in the Specification Book), the smallest specified sieve is the No. 8 (2.36 mm) and there should be less than 5% passing. When smaller sieves are used in the test, the percent retained on each is usually very small or zero.

Therefore, in a coarse Ā gradation, percents passing sieves below the bottom specification sieve are to be reported as 0% with the exception of the No. 200 (75 µm) sieve. Section 703.4 in the Specification Book includes a requirement for minus No. 200 (75 µm) material for PCC aggregates, so it will be necessary to determine the percent passing for this sieve. A coarse Ā gradation analysis, sieves for which are listed in the table below, consists of conducting a T 11 wash test on the entire sample, dry sieving the sample in a Gilson shaker with a No. 8 (2.36 mm) sieve on the bottom, and then dry sieving the minus No. 8 (2.36 mm) material in a Rotap shaker using 8 inch (203.2 mm) sieves. The finer Ā sieves may be included as interceptors above the No. 200 (75 µm) sieve, in the Rotap shaker, but any weights retained on these sieves should be mathematically added to the weight retained on the No. 200 (75 µm) sieve. Various aggregates may warrant different approaches to a coarse Ā gradation.

Fine aggregate for PCC concrete is predominantly material passing the No. 4 (4.75 mm) sieve and should have 100% passing all larger sieves. Assuming 100% passing these sieves makes testing with larger sieves unnecessary. Section 702.1.2 in the Specification Book specifies a limit for the amount of minus No. 200 (75 µm) material in fine aggregate for PCC. A fine Ā gradation analysis, sieves for which are listed in the table below, consists of a T 11 wash test and a dry sieving of the material with the 3/8 in. (9.5 mm) sieve at the top and a No. 200 (75 µm) sieve at the bottom. Various aggregates may warrant different approaches to a fine Ā gradation.

Typical Coarse Ā Gradation Analysis

Coarse Dry Sieves and Interceptors	
1 1/12 in.	(37.5 mm)
1 in.	(25.0 mm) – interceptor
3/4 in.	(19.0 mm)
1/2 in.	(12.5 mm) – interceptor
3/8 in.	(9.5 mm)
No. 4	(4.75 mm)
No. 8	(2.36 mm)
Fine Dry Sieves and Interceptors	
Various interceptor sieves	
No. 200	(75 µm)

Typical Fine Ā Gradation Analysis

Fine Dry Sieves	
3/8 in.	(9.5 mm)
No. 4	(4.75 mm)
No. 8	(2.36 mm)
No. 16	(1.18 mm)
No. 30	(600 µm)
No. 50	(300 µm)
No. 100	(150 µm)
No. 200	(75 µm)

Specifications

Specifications for evaluating Ā tolerance can be found in sections of the West Virginia Standard Specifications corresponding to the particular concrete item being produced. Specifications require that two calculated parameters be in compliance for all Ā samples. The first requirement is that the calculated Ā value falls within a certain tolerance of the target Ā value. The second requirement is related to the total percent passing the No. 200 (75 μm) sieve for the aggregates. The actual percents passing the No. 200 (75 μm) sieve for the coarse and fine aggregates are adjusted to their mix design proportions. Then the total maximum allowed percents passing the No. 200 (75 μm) sieve are calculated. The total maximum allowed minus No. 200 (75 μm) percentage is based on the specifications for each aggregate (Sections 702.1.2 and 703.4) and then adjusted to the mix proportions of each aggregate. If the total actual adjusted minus No. 200 (75 μm) percent exceeds the total maximum allowed minus No. 200 (75 μm) percent, the sample will fail. Samples must meet both requirements to be considered passing. With these two specification parameters in mind, we will now discuss their calculation.

Ā Calculations

The form used for Ā calculation is the T301 which replaces the old ST-13. A copy of this form can be seen on page 2-43. We will use an example problem to explain the calculations.

Pertinent sample information is recorded on the form; especially the type and size of aggregate which is recorded in the "CA" and "FA" spaces on the T301. Then the percentages passing each of the Ā sieves, including those assumed to be 100% or 0%, are recorded in their proper places for both the coarse and fine aggregates. Note that this information and these values have been recorded on the T301 on page 2-43. These percentages are then added together and the total divided by 100. These results rounded to the 0.01 place are the Ā values for each of the solid components in the concrete mix. Complete the calculations on the T301 on page 2-43. Answers can be checked against the completed T301 on page 2-44.

Each solid component makes up a certain fractional part, or percentage, of the total solids in the concrete mix. The Ā values for each component must be adjusted to these fractional parts before being totaled for the mix. The weights for each of these components are found in the mix design for the particular producer and specified concrete mix. The mix design weights for the coarse aggregate, fine aggregate, and cement should be recorded in the "M_{ca}", "M_{fa}", and "M_c" spaces on the T301, respectively. The fractional parts of each solid component are then calculated on the form in the space provided. It is important to note that these fractional parts should be rounded to the nearest 0.001. Perform these calculations in the example on page 2-43 and check your results on page 2-44.

The Ā values for each solid component, are to be multiplied by the fractions of each solid. This calculation is to be done on the lower left side of the T301. The results of this calculation will be the Ā values for each solid component adjusted to their relative percentage of the total solids in the concrete mix. These adjusted values are to be totaled and the result recorded in the "Ā Total Solids" space on the T301. Ā values are rounded to the 0.01 place. Complete these calculations on the example on page 2-43 and check your answers on page 2-44.

Mix designs for various types of concrete will have a target Ā value calculated and indicated on the mix design form. Specifications will set a range above and below this target value for a particular type of concrete based on the AASHTO size of aggregate used. Samples are evaluated as passing or failing based on whether their Ā values fall inside or outside of this range. Specification ranges can be found in the Standard Specifications for specific concrete items (Sections 501 and 601). Assume that the range for this item is ± 0.25 for the example problem.

Minus No. 200 (75 μm) Specification Calculations:

Recall that there is one additional check required for Ā sample evaluation, the minus No. 200 (75 μm) specification limit. Sections 702 and 703 set minus No. 200 (75 μm) material limits for various aggregate types. Before evaluation, the percents passing the No. 200 (75 μm) sieve for both the coarse and fine aggregate must be adjusted to their corresponding percentages, or fractional parts, of the total aggregate. The fractional parts of the coarse and fine aggregate can be determined as indicated on the lower right of the T301. The actual percentages passing the No. 200 (75 μm) sieve are then adjusted with these fractional parts in the bottom right hand corner of the form and the results totaled. The maximum allowable percentages passing the No. 200 (75 μm) sieve (from Sections 702.1.2 and 703.4 of the WV Specifications book) for each fraction are then adjusted and the results also totaled. If the adjusted actual minus No. 200 (75 μm) percentage total does not exceed the adjusted maximum percentage total, then the sample will pass. Perform these calculations on the T301 on page 2-43 and check your results on page 2-44.

Evaluate the sample assuming the Ā tolerance listed above and the minus No. 200 (75 μm) criteria described above. Check you answer on page 2-44. Complete the problem on page 2-45 and check with the example on page 2-46.

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WEST VIRGINIA DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOIL AND TESTING
Ā CALCULATION WORKSHEET

F. S. # ____
Tech. ____
Date ____

Lab Number	Project and Contract			Date Sampled	Transmit Date
	C				

Test Sequence	Material Code	Quantity	Item Number	Plant Source Code	Aggregate Source Code

Sieves:	1st	2nd	3rd	4th	5th	6th	7th	8th	No. 200
Design Number				Unit Weight	Face Fracture % One	% Two	LL	PL	PI
AASHTO Size		Smallest Sieve 100%	Target A-bar 5.07	Actual A-bar	FA A-bar	CA No. 200	FA No. 200	Total No. 200	P/F/N

Plant Name ____ Source Coarse Agg. ____

Technician ____ Date ____ Source Fine Agg. ____

Class of Concrete ____ Cmnt Fact ____ Field Sample # ____

Sieves	CA #57 Lmst	FA Silica Sand	Cement
1 1/2 in. % pass	100	100	100
3/4 in. % pass	100	100	100
3/8 in. % pass	30	100	100
No. 4 % pass	2	99	100
No. 8 % pass	2	87	100
No. 16 % pass	0	70	100
No. 30 % pass	0	53	100
No. 50 % pass	0	14	100
No. 100 % pass	0	4	100
No. 200 % pass	1.1	2.2	100
Total			#NAME?
Solid Ā 's			#NAME?

Total Mass of Each Solid at SSD in One yd^3 of Concrete From Mix Design

M_{ca}	1724	lb
M_{fa}	1385	lb
M_{ca} + M_{fa}		lb
*M_c	518	lb
M_t		lb

Fractional Part of Each Solid (0.001)

$\frac{M_{ca}}{M_t}$ = ____ = ____

$\frac{M_{fa}}{M_t}$ = ____ = ____

$\frac{*M_c}{M_t}$ = ____ = ____

* Include Mass of Fly Ash When Used.

Solid Fraction x Each Solid Ā

Coarse Agg		x		=		$\bar{A}_{ca}$
Fine Agg		x		=		$\bar{A}_{fa}$
Cement		x	10.00	=		$\bar{A}_c$

Fractional Part of Coarse and Fine Agg. (0.001)

$F_{ca} = \frac{M_{ca}}{M_{ca} + M_{fa}}$ = ____ = ____

$F_{fa} = \frac{M_{fa}}{M_{ca} + M_{fa}}$ = ____ = ____

Adjusted and Maximum Minus No. 200 Based on Fractional Part of Total Aggregate (0.01)

	- No. 200 % pass	x	F_{ca} or F_{fa}	=		Adjusted Total - 200 CA + FA
CA		x		=		
FA		x		=		

	- No. 200 Spec Limit	x	F_{ca} or F_{fa}	=		Max. Allowed Total - 200 CA + FA
CA	1.5	x		=		
FA	3.0	x		=		

Ā Total Solids $\bar{A}_{ca} + \bar{A}_{fa} + \bar{A}_c$ ____

Target Ā 5.07

Ā Tolerance ± ____

Total Ā P/F ____

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Lab Number			Project and Contract	C		Date Sampled			Transmit Date
Test Sequence		Material Code	Quantity			Item Number	Plant Source Code		Aggregate Source Code
Sieves:	1st	2nd	3rd	4th	5th	6th	7th	8th	No. 200
Design Number				Unit Weight	Face Fracture % One	% Two	LL	PL	PI
AASHTO Size		Smallest Sieve 100%	Target A-bar 5.07	Actual A-bar #NAME?	FA A-bar #NAME?	CA No. 200 1.1	FA No. 200 2.2	Total No. 200 #NAME?	P/F/N

Plant Name		Source Coarse Agg.	
Technician	Date	Source Fine Agg.	
Class of Concrete	Cmnt Fact	Field Sample #	

Sieves	CA #57 Lmst	FA Silica Sand	Cement
1 1/2 in. % pass	100	100	100
3/4 in. % pass	100	100	100
3/8 in. % pass	30	100	100
No. 4 % pass	2	99	100
No. 8 % pass	2	87	100
No. 16 % pass	0	70	100
No. 30 % pass	0	53	100
No. 50 % pass	0	14	100
No. 100 % pass	0	4	100
No. 200 % pass	1.1	2.2	100
Total	#NAME?	#NAME?	#NAME?
Solid Ā 's	#NAME?	#NAME?	#NAME?

Total Mass of Each Solid at SSD in One yd^3 of Concrete From Mix Design

M_{ca}	1724	lb
M_{fa}	1385	lb
$M_{ca} + M_{fa}$	3109	lb
$*M_c$	518	lb
M_t	3627	lb

Fractional Part of Each Solid (0.001)

$\frac{M_{ca}}{M_t} = \frac{1724}{3627} =$ #NAME?

$\frac{M_{fa}}{M_t} = \frac{1385}{3627} =$ #NAME?

$\frac{*M_c}{M_t} = \frac{518}{3627} =$ #NAME?

* Include Mass of Fly Ash When Used.

Solid Fraction x Each Solid Ā

Coarse Agg	#NAME?	x	#NAME?	=	#NAME?	$\bar{A}_{ca}$
Fine Agg	#NAME?	x	#NAME?	=	#NAME?	$\bar{A}_{fa}$
Cement	#NAME?	x	10.00	=	#NAME?	$\bar{A}_c$

Fractional Part of Coarse and Fine Agg. (0.001)

$F_{ca} = \frac{M_{ca}}{M_{ca} + M_{fa}} = \frac{1724}{3109} =$ #NAME?

$F_{fa} = \frac{M_{fa}}{M_{ca} + M_{fa}} = \frac{1385}{3109} =$ #NAME?

Adjusted and Maximum Minus No. 200 Based on Fractional Part of Total Aggregate (0.01)

Ā Total Solids	$\bar{A}_{ca} + \bar{A}_{fa} + \bar{A}_c$	#NAME?
Target Ā		5.07
Ā Tolerance ±		0.25
Total Ā P/F		#NAME?

- No. 200 % pass	x	F_{ca} or F_{fa}	=		Adjusted Total - 200 CA + FA
CA	1.1	x #NAME?	=	#NAME?	
FA	2.2	x #NAME?	=	#NAME?	#NAME?

- No. 200 Spec Limit	x	F_{ca} or F_{fa}	=		Max. Allowed Total - 200 CA + FA
CA	1.5	x #NAME?	=	#NAME?	
FA	3.0	x #NAME?	=	#NAME?	#NAME?

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MATERIALS CONTROL, SOIL AND TESTING
Ā CALCULATION WORKSHEET

F. S. # ____
Tech. ____
Date ____

Lab Number			Project and Contract		Date Sampled			Transmit Date
			C					
Test Sequence	Material Code		Quantity		Item Number	Plant Source Code		Aggregate Source Code
Sieves:	1st	2nd	3rd	4th	5th	6th	7th	8th	No. 200
Design Number				Unit Weight	Face Fracture % One	% Two	LL	PL	PI
AASHTO Size		Smallest Sieve 100%	Target A-bar 5.40	Actual A-bar	FA A-bar	CA No. 200	FA No. 200	Total No. 200	P/F/N

Plant Name ____ Source Coarse Agg. ____

Technician ____ Date ____ Source Fine Agg. ____

Class of Concrete ____ Cmnt Fact ____ Field Sample # ____

Sieves	CA #57 Gravel UC	FA Lmst Sand	Cement
1 1/2 in. % pass	100	100	100
3/4 in. % pass	100	100	100
3/8 in. % pass	46	100	100
No. 4 % pass	6	96	100
No. 8 % pass	2	83	100
No. 16 % pass	0	65	100
No. 30 % pass	0	43	100
No. 50 % pass	0	10	100
No. 100 % pass	0	3	100
No. 200 % pass	2.3	2.9	100
Total			#NAME?
Solid Ā 's			#NAME?

Total Mass of Each Solid at SSD in One yd^3 of Concrete From Mix Design

M_{ca}	1740	lb
M_{fa}	1184	lb
$M_{ca} + M_{fa}$		lb
$*M_c$	657	lb
M_t		lb

Fractional Part of Each Solid (0.001)

$\frac{M_{ca}}{M_t}$ = ____ = ____

$\frac{M_{fa}}{M_t}$ = ____ = ____

$\frac{*M_c}{M_t}$ = ____ = ____

* Include Mass of Fly Ash When Used.

Solid Fraction x Each Solid Ā

Coarse Agg		x		=		$\bar{A}_{ca}$
Fine Agg		x		=		$\bar{A}_{fa}$
Cement		x	10.00	=		$\bar{A}_c$

Fractional Part of Coarse and Fine Agg. (0.001)

$F_{ca} = \frac{M_{ca}}{M_{ca} + M_{fa}}$ = ____ = ____

$F_{fa} = \frac{M_{fa}}{M_{ca} + M_{fa}}$ = ____ = ____

Adjusted and Maximum Minus No. 200 Based on Fractional Part of Total Aggregate (0.01)

	- No. 200 % pass	x	F_{ca} or F_{fa}	=		Adjusted Total - 200 CA + FA
CA		x		=		
FA		x		=		

	- No. 200 Spec Limit	x	F_{ca} or F_{fa}	=		Max. Allowed Total - 200 CA + FA
CA	1.0	x		=		
FA	5.0	x		=		

Ā Total Solids $\bar{A}_{ca} + \bar{A}_{fa} + \bar{A}_c$ ____

Target Ā 5.40

Ā Tolerance ± ____

Total Ā P/F ____

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WEST VIRGINIA DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOIL AND TESTING
Ā CALCULATION WORKSHEET

F. S. # ______
Tech. ______
Date ______

Lab Number		Project and Contract			Date Sampled			Transmit Date
			C					
Test Sequence	Material Code		Quantity		Item Number	Plant Source Code		Aggregate Source Code
Sieves:	1st	2nd	3rd	4th	5th	6th	7th	8th	No. 200
Design Number				Unit Weight	Face Fracture % One	Face Fracture % Two	LL	PL	PI
AASHTO Size		Smallest Sieve 100%	Target A-bar	Actual A-bar	FA A-bar	CA No. 200	FA No. 200	Total No. 200	P/F/N
			5.40	#NAME?	#NAME?	2.3	2.9	#NAME?	#NAME?

Plant Name ______ Source Coarse Agg. ______

Technician ______ Date ______ Source Fine Agg. ______

Class of Concrete ______ Cmnt Fact ______ Field Sample # ______

Sieves	CA #57 Lmst	FA Silica Sand	Cement
1 1/2 in. % pass	100	100	100
3/4 in. % pass	100	100	100
3/8 in. % pass	46	100	100
No. 4 % pass	6	96	100
No. 8 % pass	2	83	100
No. 16 % pass	0	65	100
No. 30 % pass	0	43	100
No. 50 % pass	0	10	100
No. 100 % pass	0	3	100
No. 200 % pass	2.3	2.9	100
Total	#NAME?	#NAME?	#NAME?
Solid Ā 's	#NAME?	#NAME?	#NAME?

Total Mass of Each Solid at SSD in One yd^3 of Concrete From Mix Design

M_{ca}	1740	lb
M_{fa}	1184	lb
M_{ca} + M_{fa}	2924	lb
$*M_c$	657	lb
M_t	3581	lb

Fractional Part of Each Solid (0.001)

$\frac{M_{ca}}{M_t} = \frac{1740}{3581} =$ #NAME?

$\frac{M_{fa}}{M_t} = \frac{1184}{3581} =$ #NAME?

$\frac{*M_c}{M_t} = \frac{657}{3581} =$ #NAME?

* Include Mass of Fly Ash When Used.

Solid Fraction x Each Solid Ā

Coarse Agg	#NAME?	x	#NAME?	=	#NAME?	$Ā_{ca}$
Fine Agg	#NAME?	x	#NAME?	=	#NAME?	$Ā_{fa}$
Cement	#NAME?	x	10.00	=	#NAME?	$Ā_c$

Fractional Part of Coarse and Fine Agg. (0.001)

$F_{ca} = \frac{M_{ca}}{M_{ca} + M_{fa}} = \frac{1740}{2924} =$ #NAME?

$F_{fa} = \frac{M_{fa}}{M_{ca} + M_{fa}} = \frac{1184}{2924} =$ #NAME?

Ā Total Solids	$Ā_{ca} + Ā_{fa} + Ā_c$	#NAME?
Target Ā		5.40
Ā Tolerance ±		0.25
Total Ā P/F		#NAME?

Adjusted and Maximum Minus No. 200 Based on Fractional Part of Total Aggregate (0.01)

	- No. 200 % pass	x	F_{ca} or F_{fa}	=		Adjusted Total - 200 CA + FA
CA	2.3	x	#NAME?	=	#NAME?	
FA	2.9	x	#NAME?	=	#NAME?	#NAME?

	- No. 200 Spec Limit	x	F_{ca} or F_{fa}	=		Max. Allowed Total - 200 CA + FA
CA	1.0	x	#NAME?	=	#NAME?	
FA	5.0	x	#NAME?	=	#NAME?	#NAME?

CHAPTER 3

DOCUMENTATION

SECTION 3.1

QUALITY CONTROL PLAN

The Inspector must be familiar with the provisions of the Contractors Quality Control Plan. **<u>The minimum requirements of the Quality Control plan are contained in MP 601.03.50</u>**.

The Quality Control plan covers the type and frequency of sampling and testing deemed necessary to measure the magnitude of the various properties of concrete. It also includes inspection and calibration of equipment used in the production of concrete to reduce any inaccuracies in batching and mixing procedures.

The inspector should verify that the required inspections, calibrations, control charts, and other documentation requirements of the Quality Control plan are accomplished. The inspector should keep appropriate records documenting any significant occurrences at the plant that relate to the Quality Control Plan and plant operations.

A Concrete Batch Ticket must accompany each load of concrete that leaves the plant. This batch ticket must be a pre-printed batch ticket supplied by the plant (as detailed in sections 2.4.3 through 2.4.6 of MP 601.03.50). The inspector should ensure that plant personnel are completing the form properly.

It is important that all entries are completed and are accurate. The material codes for many WVDOH classes of concrete are listed in Section 3.2 (page 3-6).

A sequence number is assigned at the plant for all loads going to DOH projects. The first load leaving the plant will be assigned 001, the second load 002 and so on, consecutively for each day’s production. The entry for "Water Plant" must include both the free moisture batched with the aggregates and the water metered separately into the batch.

The date entry is a two-digit number for the month, day, and year respectfully. For example, November 10, 2006 would be entered as <u>11</u> <u>10</u> <u>06</u>.

The cylinder ID is a two-digit number that corresponds to the first two numbers assigned as the Field Sample Number on the T-702 for that set of cylinders.

Items required on a batch ticket are listed below (and in MP 601.03.50).

Each batch of Structural Concrete and Pavement Concrete (on which a test is to be performed) delivered at the project shall be accompanied by one batch ticket.

All batch tickets for Structural Concrete and Portland Cement Concrete Pavement Concrete transported by truck mixers shall have all of the following items pre-printed on the ticket:

Source Code, Source Name, Source Location, Mix Design Number, Date, Sequence Number, Volume (yd^3/m^3), Time Batched, Time Unloaded, Authorization Number, Material Code, Material Name, Water Allowed (Gallon/Liter), Water at Plant (Gallon/Liter), Water at Job (Gallon/Liter), Weight Cement (lb/kg), Weight Pozzolan (lb/kg), Temperature ($^oF/ ^oC$), Cylinder I.D., Initial Counter, Final Counter, Target Consistency (in/mm), Actual Consistency (in/mm), Target Air (%), Actual Air (%), Truck Number

All batch tickets for pavement concrete delivered by means of nonagitator trucks or truck agitators shall have all of the following items pre-printed on the ticket:

Source Name, Mix Design Number, Date, Sequence Number, Volume (yd^3/m^3), Time Batched, Time Unloaded, Authorization Number, Material Code, Material Name, Water Allowed (Gallon/Liter), Water at Plant (Gallon/Liter), Weight Cement (lb/kg), Weight Pozzolan (lb/kg), Temperature ($^oF/ ^oC$), Target Consistency (in/mm), Actual Consistency (in/mm), Target Air (%), Actual Air (%), Truck Number

The inspector should also verify the accuracy of the Weekly Suppliers Report (Form HL-441). At the end of each production week the total amounts of materials used are summarized on the form. This is a very important form as it provides necessary information used in coverage procedures. A sample copy of form HL-441 follows.

Instructions for completing this form are on the backside of the form and are repeated on page 3-5 of this manual.

WEEKLY SUPPLIERS REPORT
FORM HL-441 Rev. (T) 3-9-70

WEST VIRGINIA DEPARTMENT OF HIGHWAYS

SHEET____OF__________

INSTRUCTIONS: ORIGINAL REMAINS AT SUPPLIER. ONE COPY TO DIST. MAT. OFFICE FOR REVIEW, REPRODUCTION AND DISTRIBUTION TO EACH PROJECT LISTED HEREIN.

1. TYPE OF MATERIAL	2. SOURCE	3. DATE OF REPORT

4. SUPPLIER	5. SAMPLING FREQUENCY		☐ CENTRAL LAB.	☐ DISTRICT LAB.	☐ PLANT LAB.
		TYPE			
		FREQUENCY			

REPORTED BY: WVDH INSPECTOR	REVIEWED BY	TITLE	DATE

6. DATE SHIPPED	7. DIST. NO.	8. PROJECT OR BRIDGE NUMBER	9. CONT. NO.	10. QTY. DEL'D TO JOB			11. FIELD LAB.NO.	12. DISTRICT OR CENTRAL LAB. NO.	13. GRADATION		14. CONVER. FACTOR	15. REMARKS
						CUM. TOTAL			A.M.	P.M.		

INSTRUCTIONS FOR PREPARING FORM HL-441

WEEKLY SUPPLIERS REPORT

1. Type of Material - Enter here the description of material, such as sand, stone, asphalt, cement, etc. with identifying size number when applicable.
2. Source - Enter here the location from which material was produced.
3. Date of Report - Enter here the date the report is prepared.
4. Supplier - Enter here the name and location of the firm which is furnishing the material
5. Sampling Frequency - Enter here the sampling frequencies as per Construction Manual Sub-Section 700.02. Place an (x) in the block to designate the lab where the material has been tested.
6. Date Shipped - Enter here the date material is shipped to the project.
7. District No. - Enter here the District to which the material is shipped.
8. Project or Bridge No. - Enter here the number of the project or bridge where material will be used.
9. Contract No. - Enter here the contract number when applicable.
10. Quantity Delivered to Job - The two blank columns will be used to show whether the material is in tons, cubic yards, square yards, etc. Cumulative total - enter total amount shipped to date. In case of Portland Cement Concrete, the balance of these materials may be carried in place of Cumulative Totals, if so desired.
11. Field Lab. No. - Enter here the number assigned to sample taken in the field.
12. Lab. No. - Enter here the number assigned to the tested material from the appropriate laboratory.
13. Gradation - Place a P (Passing) or F (Failing) under the column a.m. when gradations are made in the morning or under p.m. when gradations are made in the afternoon.
14. Conversion Factor - Enter here the conversion factor as per Job Mix Formula.
15. Remarks - Enter here all pertinent information where no column has been provided.

SECTION 3.2

FORM T-100

Form T-100 (formerly T-702) is used to provide all pertinent information, concerning a sample, to the testing laboratory. This information will also appear on the completed test report Form T7. Following are some specific applications to concrete cylinders:

1. Materials Description (Class of Concrete)	Mat. Code (English)	Mat. Code (Metric)
Class A Concrete	1290	3290
Class B Concrete	1286	3286
Class B with Fly Ash	1924	3924
Class B with GGBFS	1099	3099
Class B Mass Concrete 3000 PSI	1925	
Class B Mass Concrete 4000 PSI	1926	
Class B Modified 3500 PSI (24 Mpa)	1380	3380
Class B Modified 4000 PSI (28 Mpa)	1381	3381
Class B Modified 4500 PSI (31 Mpa)	1382	3382
Class B Modified 4500 PSI with Fly Ash	1387	
Class B Modified 5000 PSI (34 Mpa)	1383	3383
Class B Modified 6000 PSI	1386	
Class C Concrete	1287	3287
Class D Concrete	1288	3288
Class K Concrete 4500 PSI	1911	3911
Class K Concrete 4000 PSI (28 Mpa)	1963	3963
Class K 4500 PSI (31 Mpa) with Fly Ash	1923	3923
Class K 4000 PSI (28 Mpa) with Fly Ash	1962	3962
Class K 4500 PSI (31 Mpa) with GGBFS	1098	3098
Class K 4000 PSI (28 Mpa) with GGBFS	1074	3074
Class H	1291	3291
Class H Modified 6000 PSI	1282	
Pavement Concrete	1285	3285
Pavement Concrete with Fly Ash	1378	3378
Pavement Concrete with GGBFS	1097	3097
Latex Modified Concrete	1384	3384
Microsilica Concrete	1998	3998

Preceding the material code is another code that further describes the nature of the sample. For concrete cylinders this code is normally 2, which indicates "Job Control."

2. Field Sample Number: The first two characters of the field sample number must match the cylinder I.D. assigned on the concrete batch tickets.
3. Any special instruction or other pertinent information should be noted in the "Remarks" section. Unless otherwise noted, the receiving laboratory will test cylinders at an age of 28 days.

CHAPTER 4

CONCRETE SAMPLING METHODS

CHAPTER 4

SAMPLING IS AS EQUALLY IMPORTANT AS TESTING

If a sample is not representative of the lot it was taken from, then the test result represents only the sample (not the lot from which it was taken). Improper sampling can cause a rejection of good and acceptable concrete. It can also cause the acceptance of undesirable concrete. A composite sample of any concrete mixture should represent an average of all characteristics of the lot from which it was taken. In other words, a sample is a small quantity that should be a duplicate (or what is known as representative) of a larger quantity of material.

There is a method of sampling for every situation that can be practical and very easily applied. Before sampling, you should assure yourself that you have all of the necessary equipment and supplies required to complete the job. A container will be needed, such as a shovel, bucket, wheelbarrow, or a concrete buggy. Any one of the containers may be all you need, or probably a combination such as a shovel and wheelbarrow. A supply of rags and water is a necessity. All equipment coming in contact with the concrete will have to be wiped with a damp cloth to prevent absorbing the mix water. Also the equipment will have to be cleaned shortly after being used.

Acceptance sampling and testing of Portland cement concrete is the responsibility of the Division, except for furnishing of necessary equipment. There are two types of samples. These are quality control samples and acceptance samples. Quality control samples and tests from the Contractor **may** be used by the Division for acceptance.

Sampling of fresh concrete is governed by the procedures outlined in AASHTO Designation R-60. Composite samples are required by this method. As stated earlier, a composite sample should provide a better representative average of the characteristics of a batch of concrete than a single sample. When compressive strength specimens are to be fabricated from a composite sample, the slump, air content, and temperature are also to be tested for from the same sample.

For acceptance testing, and when sampling from revolving drum truck mixers or agitators, sample the concrete in question at least twice during the discharge of the middle portion of the batch.

Sampling should normally be performed as the concrete is delivered from the mixer to the conveying vehicle used to transport the concrete to the forms. However, samples should be taken as close as possible to the final placement point of the concrete, such as at the discharge of the pump when a concrete pump is used to transport the concrete.

Obtain these samples as quickly as possible. The first and last portions of the composite sample must be obtained within 15 minutes of each other. The two or more samples obtained from the middle portion of the batch should then be combined and re-mixed to form a composite sample. No sample should be taken before 10% or after 90% of the batch has been discharged, and do not obtain the samples until after all of the water and any admixtures have been added. As in any sampling procedure, the sampler must make sure there is enough sample to perform all of the intended tests. The volume of this composite sample must be at least one cubic foot. Slump, temperature, and air tests are to be started within 5 minutes of obtaining the final portion of the composite sample. The fabrication of strength specimens (molding cylinders) is to begin within 15 minutes after obtaining the composite sample.

The sample must be covered with a damp cloth or a non-absorbent fabric until all test portions have been removed from the sample pile. This protects the sample and prevents the evaporation of moisture, which in turn makes the sample non-representative of the batch material.

Air and slump tests needed before concrete placement is started (used to determine if placement is allowed to begin) must obviously be taken before the discharge of the middle portion of the batch. **These types of tests are quality control tests**. For these quality control tests (for which strength specimens are not required), AASHTO R-60 permits the sample to be taken after a minimum of one-fourth of a cubic yard (0.25 yd^3) of concrete has been discharged. **<u>However, all samples that are to be used for acceptance testing must be obtained from the</u>**

middle portion of the discharge. Remember, no portion of any sample can be taken from the very beginning or end of the discharge.

Sampling for acceptance testing must be in accordance with AASHTO R-60. **It is mandatory that any acceptance sample be taken after all field adjustments (such as adding water or air) have been made.** An acceptance sample will not be valid if water or air are added after the acceptance sample is taken. **AASHTO R-60 states that no acceptance sample should be taken before 10% or after 90% of the batch has been discharged.** The intent of this requirement is to ensure that the composite sample is not taken from the beginning or the end of the load.

In accordance with his Quality Control Plan, the Contractor is obligated to perform minimum quality control testing at the same frequency as acceptance testing. These required testing frequencies are outlined in MP 601.03.50.

For these tests the Contractor must use the procedures of AASHTO R-60 since the Department has the option to use his results for acceptance. The contractor may also perform additional tests at his option as part of his process control.

With these procedural guidelines in mind we will now discuss the application of the most practical sampling methods.

When sampling a **truck mixer**, the most representative characteristics can be gained by taking the sample in two portions from the middle part of the load. The first portion must be covered with a damp cloth or non-absorbing material while waiting to take the second portion. Also, remember that the second portion must be taken within fifteen minutes of taking the first portion. If you choose to take three samples from the middle half of the load, then the third sample must be taken within fifteen minutes of the first sample, etc. The testing cannot begin until all samples have been composited into one sample and the sample re-mixed, generally with a shovel or a large scoop.

If the concrete is mixed in a **stationary mixer (other than paving mixers)** and transported in a truck mixer or agitator, you may take the sample as outlined above. You may also take the sample at the mixing site. A mixer of this type generally empties its entire contents in approximately 3 to 5 seconds. Therefore, you will not be concerned about the time limitations between first and final portion. This type of operation is especially difficult to sample since the discharge generally cannot be intercepted. It would probably be more practical to sample this type of operation at the placement site.

If the concrete is mixed in a **paving mixer**, and transported in a truck other than a truck mixer, the concrete must be sampled after the contents of the paving mixer have been discharged onto the subgrade. Obtain samples from at least five different portions of the pile and then combine them into one sample for test purposes. Avoid contamination with the subgrade material or prolonged contact with an absorptive subgrade. To minimize contamination or absorption by the subgrade, the concrete may also be sampled by placing three shallow containers on the subgrade and discharging the concrete across the containers. Combine the samples into one sample for test purposes.

When the concrete contains aggregate larger than that appropriate for the size of the molds or testing equipment to be used, wet-sieve the sample as described below, except perform the unit weight test on the full mix. This situation will most likely never occur on WVDOH projects, as the maximum size aggregate (#57 or #67) will typically be small enough that standard testing equipment can be used without going through the wet-sieving procedure.

Wet-sieving concrete is the process of removing aggregate larger than a designated size from the fresh concrete by sieving it on a sieve of the designated size (typically a 1-inch, 1.5 inch, or 2-inch sieve, depending on the molds and/or equipment being used).

After sampling the concrete, pass the concrete over the sieve and remove and discard the aggregate retained on the sieve. This shall be done before remixing. Shake or vibrate the sieve until no material continues to pass through the sieve. Mortar adhering to the aggregate retained on the sieve shall not be wiped from it before the aggregate is discarded. Place only enough concrete on the sieve at any one time so that after sieving, the thickness of the layer of aggregate is not more than one particle thick. The concrete that passes through the sieve shall fall into a clean, moist pan of suitable size. Scrape any mortar adhering to the sides of the wet-sieving equipment into this pan. After removing the larger aggregate particles by wet-sieving, remix the concrete in the pan with a shovel to ensure uniformity.

Question

True or False? A one cubic foot sample may be taken from the middle portion of a load of concrete to determine additional quality control information.

Turn to the next page for the answer.

The statement is true. Remember that quality control tests on fresh concrete should be conducted quite frequently, especially until a mix design has been proven to yield all characteristics expected of it. After this fact has been established the frequency of quality control sampling and testing may be decreased.

If you thought the statement to be untrue, you were wrong. Quality control samples may be taken any time, but the sampler should try to keep the sample representative. Quality control samples are taken at the first part of discharge (after one-fourth of a yard of discharge) so that the characteristics of the concrete (air content, consistency) are known before including the concrete into the job (they may also be taken during discharge also). This prevents the acceptance of undesirable concrete. Acceptance samples are then taken from the middle portion of the discharge.

Air content can be directly related to the ability of concrete to resist freezing and thawing. Consistency is related to water-cement ratio, and water-cement ratio is directly related to strength.

CHAPTER 5

TESTING

SECTION 5.1

TEMPERATURE

Webster defines temperature as a degree of hotness or coldness measured on a definite scale. The instrument for measuring temperature is called a thermometer. This instrument makes use of the principle that substances expand when heated and contract when cooled. The expanding substance may be a liquid, such as mercury or alcohol; a gas such as hydrogen, nitrogen, or air; or a solid, such as metal.

Section 601.9 of the Standard Specifications covers concreting during adverse conditions. Section 601.9.2 states that when a shaded thermometer in the vicinity of the concrete production plant reaches 85 °F the temperature of the plastic concrete shall be taken at least hourly. When the temperature of the plastic concrete reaches 85 °F, the time limit from when the mixing water is added to the cement-aggregates until discharge of the mix is reduced to one hour.

These specifications require immediate action when the temperature of the plastic concrete reaches 90 °F. Steps shall be taken to cool either the mixing water or aggregates, or both in order to maintain a plastic concrete temperature of 90 °F or less. If ice is used to cool the mixing water, the ice must be considered as part of the mix water in the mix proportions.

Section 601.9.1 of the Standard Specifications states that the temperature of the plastic concrete shall be at least 50 °F, but not more than 85 °F at the time of placement during cold weather. Maintenance of at least the minimum temperature shall be accomplished by heating the water or the aggregates or both. When the plastic concrete has a temperature of less than 55 °F, the provisions for cold weather concreting shall apply.

The temperature should be checked on pavement concrete whenever the concrete temperature is suspected of nearing specification limits and at the time of regular tests. The procedure for obtaining the temperature of freshly mixed concrete is covered in ASTM C 1064.

This test may be made in a wheelbarrow or in the fresh concrete during placement. When obtaining the temperature of a concrete sample, the temperature measurement must be completed within five minutes of obtaining the sample. The thermometer (calibrated annually and accurate to within ±1 °F throughout a range of 30° to 120°F) should be submerged in the concrete and remain in the concrete for at least two minutes but not more than five minutes. The temperature-sensing portion of the measuring device should be surrounded on all sides by at least three inches of plastic concrete. Record the measured temperature to the nearest 1 °F (0.5 °C). Do not remove the thermometer from the concrete when reading the temperature.

SECTION 5.2

CONSISTENCY (SLUMP)
AASHTO T 119

The consistency of Portland cement concrete is a measure of the freshly mixed concrete's ability to flow. This property is important because concrete must have the proper consistency and workability for different applications. For example, a higher slump concrete (more flowable) would be desirable when reinforcing steel is spaced close together or when concrete is being placed by pumping.

Factors such as water content, types and amounts of admixtures used in the mix, aggregate type and gradation, and many others will all affect the slump of concrete.

In determining the consistency of Portland cement concrete a test referred to as a "Slump Test" is performed. When performing a slump test it should be in accordance with the Method of Test for "Slump of Hydraulic Cement Concrete" (AASHTO Designation T 119).

The first assignment for running the slump test is to check all equipment to be sure that it meets specifications. **When the slump cone is first placed in service and at least once a year after that, check and record the slump cone's dimensions to see if they conform to the specified dimensions.** You also would want to check the equipment for hardened concrete and damage. The following is a list of equipment you will need for this test:

1. Slump Cone
2. Scoop
3. Tamping Rod (5/8 inch diameter, 16 to 24 inches long, and with a rounded hemispherical tip)
4. Ruler

Now that you are familiar with the equipment to be used, you need a flat, level, moist, nonabsorbent (rigid) surface on which to conduct the test.

Our first operation is to level the testing surface and to assure ourselves that it is stable and rigid. This may be accomplished by using a shovel and shims. The shims are used to level the surface. Then shovel loose material under the surface (to fill the void space) and compact the material so that the testing surface is completely stable. Then take a damp cloth and dampen the surface and all of the equipment that is to be used in the test. All of the equipment should be in close proximity and within reach while running the test.

At this point you are ready for the sample of concrete on which the test will be conducted. The sample shall be obtained in accordance with the instruction contained in Chapter 4 of this manual (or AASHTO R 60). The sample thus obtained shall be mixed with a shovel or scoop until it is uniform in appearance.

The slump test must be started within 5 minutes after obtaining the final portion of the composite sample. The entire operation from the start of the filling of the mold through the removal of the mold shall be carried out without interruption and shall be completed within an elapsed time of 2½ minutes.

Be sure that the slump cone is damp, and then place the large end of the cone on the testing surface and hold the cone firmly in place by standing on the foot-pieces. At this point, recheck yourself to be absolutely certain that all of your equipment is damp and within easy reach, also that you are within easy reach of the test sample. This is done so that a measurement may be made immediately and you don't take a chance of jarring the concrete by walking around on the testing surface hunting for equipment.

Now that the cone is firmly held in place we may start adding the first layer of concrete. The concrete should be added with the scoop in a twisting motion so that it is uniformly distributed over the bottom of the mold. Fill the mold up to a height of one third of the volume of the cone (a height of approximately 2 5/8 inches). The concrete is then rodded 25 times over the cross-section of the cone. Since this is the bottom layer it is necessary to tilt the rod slightly since the bottom of the mold is larger than the top. The strokes should be made to spiral around the cone, beginning near the perimeter of the cone and ending in the center of the cone. Rod the bottom layer throughout its depth.

The second layer is then added to fill the cone to a height of two thirds of the volume of the cone (a depth of approximately 6 1/8 inches). Again the concrete is added with the scoop in a twisting motion so that it is uniformly distributed inside the mold. The concrete is then rodded 25 times throughout its depth, so that the strokes penetrate approximately 1 inch into the underlying layer. The strokes also should be made to spiral around the cone and to end in the center of the cone.

The third layer is then immediately added by twisting the scoop to uniformly distribute the concrete until the cone is overfilled. The concrete should be heaped above the cone because it tends to subside as the rodding is performed. If the concrete level should subside, add additional concrete to keep an excess of concrete above the top of the mold at all times. This third layer is also rodded 25 times. So, remember if rodding has begun and the level of the concrete subsides below the cone, add additional concrete and continue where you had stopped rodding. <u>At no time will you rod any one layer more than 25 times during the test</u>. One of the most common mistakes made in conducting the slump test is improper rodding of the third layer.

If you remember when we discussed the rodding of the second layer, you were to rod through the depth of the concrete and penetrate approximately 1 inch into the underlying layer. This third layer should be rodded in the same manner. Since the slump cone is 12 inches ± 1/8 inch tall this would mean that to rod through the depth of the third layer your rod would have to penetrate approximately 7 inches inside the cone.

After the top layer has been rodded, strike off the surface of the concrete by means of a screeding and rolling motion of the tamping rod. When all concrete is removed from around the base of the cone, transfer your weight from the foot pieces to the handles. Then step off the foot pieces and raise the mold immediately from the concrete by raising it carefully in a vertical direction.

If at any time up to this point during the test the cone is shifted or moved, the test becomes invalid and must be started again. Therefore, it is very important to keep your feet firmly on the foot-pieces and not move the slump cone.

Raise the mold a distance of 12 inches in 5 ± 2 seconds by a steady upward lift with no lateral or torsional motion. Complete the entire test, from the start of the filling through removal of the mold, without interruption, and complete it within an elapsed time of 2 1/2 minutes.

Immediately measure the slump by determining the vertical difference between the top of the mold and the displaced original center of the top surface of the specimen. One easy way to determine the location of the original displaced center of the specimen is to place a small coin at the center of the top of the specimen after it has been screeded off, but before the cone is removed. Once the cone is removed, this coin will be located at the original displaced center. Record the slump in terms of inches to the nearest 1/4 inch of subsidence of the specimen.

If a decided falling away or shearing off of concrete from one side or portion of the mass occurs, disregard the test and make a new test on another portion of the sample.

If two consecutive tests on a sample of concrete show a falling away or shearing off of a portion of the concrete from the mass of the specimen, the concrete probably lacks the necessary plasticity and cohesiveness for the slump test to be applicable.

Question:

1. How deep would you have to rod the third layer of the slump cone in order to penetrate into the underlying layer?

1.1 7 inches.

1.2 4 inches.

For the answers, turn to the next page.

1.1 CORRECT. 7 inches is correct.

1.2 WRONG CHOICE. If you will remember the layers are to be equal in volume and the last one-third of the volume of the cone is in the top 6 inches of the cone. Therefore to rod through the third layer and approximately 1 inch into the second layer, the rod will have to penetrate at least 7 inches.

SECTION 5.3

AIR CONTENT
AASHTO T 196 and AASHTO T 152

The greatest advance in concrete technology in recent years has been the advent of air-entrainment. The principal reason for using entrained air is to improve concrete's resistance to freezing and thawing. However, there are other important beneficial effects of entrained air in both freshly mixed and hardened concrete such as; workability, resistance to deicers, sulfate resistance, water tightness, abrasion resistance, and many more.

SECTION 5.3.1

AIR CONTENT OF FRESHLY MIXED CONCRETE
BY THE VOLUMETRIC METHOD (ROLL-0-METER)
AASHTO T 196

This method of test covers the procedure for determining the air content of freshly mixed concrete containing any type of aggregate, whether it is dense, cellular, or lightweight.

Division procedures require that the roll-o-meter be used for determining the air content of concrete containing slag or other porous aggregate. When using this test method, the total air (both entrained in the concrete and entrapped in the aggregates) is found. That is why the volumetric method for air content must be used for porous aggregates (the dial reading obtained from the pressure method for determining air content doesn't include the entrapped air in the aggregates). The test should be conducted in accordance with AASHTO T 196, Air Content of Freshly Mixed Concrete by Volumetric Method.

Equipment - The equipment needed for this test consists of:

1. Airmeter (bowl and top section)
2. Funnel
3. Tamping Rod (5/8 inch diameter, at least 4 inches longer than the depth of the measuring bowl with a maximum length of 24 inches, and with a rounded hemispherical tip). A rod length of 16 to 24 inches meets the requirements of this test method.
4. Strike-off Bar (either a flat, straight, steel bar at least 1/8 inch by ¾ inch by 12 inches or a flat, straight, high-density polyurethane bar at least ¼ inch by ¾ by 12 inches)
5. Calibrated Cup (with a either a capacity or being graduated in increments equal to 1.0 ± 0.04 percent of the volume of the bowl of the airmeter)
6. Measuring Vessel for Isopropyl Alcohol (at least 1 pint capacity with graduations of 4 ounces or less)
7. Syringe
8. Pouring Vessel for Water (at least 1 quart capacity)
9. Scoop
10. Mallet with a rubber or rawhide head (1.25 ± 0.5 lb)
11. Isopropyl Alcohol (70% by volume)

Calibration of Apparatus

Calibrate the meter and calibrated cup initially and at three-year intervals or whenever there is reason to believe that either of them have been damaged or deformed.

The volume of the bowl of the air meter shall be determined (to an accuracy of 0.1%) by weighing the amount of water at room temperature that is used to completely fill the bowl. This weight is then divided by the unit weight of water at the same temperature. A glass plate is used to almost completely cover the bowl so that it can be determined when the bowl is completely and level full.

The weight of bowl and plate glass must be determined prior to filling so you can subtract their weight from the total weight when full of water. If you use some form of grease around the top of the bowl and lay a piece of plate glass over it with just a small corner open, you will be able to fill the bowl to capacity with a syringe and avoid any spilling.

The accuracy of the gradations on the neck of the top section of the air meter shall be determined by filling the assembled measuring bowl and top section with 70 °F water up to the zero mark. The quantity of water added shall equal the pre-selected air content graduation within ± 0.1 volume percent of the measuring bowl. Repeat the procedure to check a minimum of three graduations within the expected range.

The volume of the measuring cup shall be checked by adding one cupful of 70 °F water to the water already in the neck. Such addition shall increase the height of the water column by the amount equivalent to 1.0 percent of indicated air. It is important to have the water at 70 °F throughout these calibrations.

Sample

A representative sample of concrete to be tested shall be obtained in accordance with the instructions contained in Chapter 4 of this manual (or AASHTO R 60). Also the air test must be started within 5 minutes after obtaining the final portion of the composite sample.

Procedure

Step 1 (filling the bowl with concrete):

Our first operation, as with previous tests, is to check all equipment for specification compliance, hardened concrete or damaged equipment. After this is determined we are ready to set up for the test. After the sample has been obtained and re-mixed we are ready to start the test. Again as with all other test methods, the equipment should be damp, so a damp rag is used to dampen the bowl, rod and scoop.

The bowl is to be filled with concrete in two layers of equal depth. The first layer, when added to the bowl, should be slightly more than one-half of the depth of the bowl. This layer is then rodded 25 times with the tamping rod, uniformly distributing the strokes around the bowl and covering the entire cross-section ending in the center of the bowl. The bowl is then tapped sharply with the mallet around the sides (10 to 15 times) to close any voids created by the rodding.

The second layer should be added to the bowl until concrete is above the top of the bowl. Again the concrete is rodded 25 times in a circular motion ending in the middle. Remember to penetrate approximately 1 inch into the underlying layer with each stroke. The bowl is again tapped with the mallet (10 to 15 times) until the voids are closed. After tapping the second layer, a slight excess (approximately 1/8 inch or less) of concrete above the rim is acceptable. Add or remove a representative sample of concrete, if necessary, to obtain the required amount of concrete.

After the concrete has been rodded and tapped it is ready to be struck off. The excess concrete should be struck off in a sawing motion with minimum manipulation necessary to get the surface flush with the top of the bowl. This is accomplished with a straight edge (strike-off bar). Over-working of the concrete will cause the fine material to float to the top. After the concrete is struck off, wipe all excess concrete from the bowl with a damp rag, being careful to clean the top and the flange of the bowl. Also clean the rubber seal located in the top section of the apparatus. Failure to get these areas clean may cause the meter to leak, which will result in an invalid test.

Step 2 (filling the meter with water and alcohol):

The top section of the apparatus is then clamped to the bowl, using care to get all three clamps tight. The special funnel is then inserted until the top of the funnel rests on top of the top section of the meter. Add at least 1 pint (16 ounces) of water followed by the selected amount of isopropyl alcohol through the funnel. The funnel is used so that the surface of the concrete is not disturbed as the water is added to the meter. The amount of alcohol necessary depends on many factors. Concrete with less than 500 lb/yd^3 of cement and air contents less than 4% may require less than 0.5 pints (8 ounces) of alcohol, but some high-cement mixes with silica fume and air contents greater than 6% may require more than 3 pints (48 ounces) of alcohol. Generally, the amount of alcohol necessary can be established for given mixture proportions and should not change much during the course of a job.

Record the amount of isopropyl alcohol added. Continue adding water through the funnel until it is visible in the graduated neck of the top section. It will take a significant amount of water to fill the meter since the entire top section is being filled.

Now, remove the funnel, and adjust the water level using the rubber syringe, until the bottom of the meniscus of the water is level with the zero mark. The screw cap is then attached and tightened. All excess water should then be wiped off the meter with a dry rag so that you will be able to detect any leak, which may develop during the agitating. If a leak should occur, discard the test and start over. At this point, the task of filling the meter is completed, and we are ready to agitate.

Step 3 (inverting and agitating the meter):

Quickly invert the meter, shake the base from side to side, and return the meter to the upright position. Do not keep the meter inverted for more than 5 seconds at a time as this may cause aggregates to become lodged in the neck. Repeatedly **invert and agitate** the meter for a minimum of 45 seconds and until the concrete has broken free from the base and the aggregate can be heard moving in the meter as it is inverted. When you are sure the concrete is loose from the base, place one hand on the neck of the meter and one hand on the flange.

Step 4 (turning and rolling the meter):

Tilt the meter approximately 45 degrees and roll the meter ¼ to ½ turn forward and back several times, quickly starting and stopping the roll. Turn the base of the meter about 1/3 turn and repeat the previously described rolling procedure. Continue the turning and rolling process for approximately one minute. The aggregate must be heard sliding in the meter during this process. **If, at any time during the inversion and rolling process, liquid is found to be leaking from the meter, the test is invalid and a new test shall be started.**

Set the meter upright and loosen the top and allow it to stand while the air rises to the top and the liquid level stabilizes. The liquid level is considered stable when it does not change more than 0.25 percent within a two-minute period. **If it takes more than six minutes for the liquid level to stabilize, or if there is more foam than the equivalent of two full percent air divisions (in the graduated neck portion of the top section) above the liquid level, discard the test and start the test again using more alcohol than was used initially.** If the level is stable without excessive foam, read the bottom of the meniscus to the nearest 0.25 percent and record this as the initial meter reading. If the air content is greater than the 9 percent range of the meter, add a sufficient number of calibrated cups of water to bring the liquid level up into the graduated neck portion of the top section of the meter. Read the bottom of the meniscus to the nearest 0.25 percent and record the number of calibrated cups of water that were added.

After the initial meter reading is obtained, retighten the top and repeat the one minute turning and rolling process. Once again, set the meter upright and loosen the top and allow it to stand while the air rises to the top and the liquid level stabilizes. The liquid level is considered stable when it does not change more than 0.25 percent within a two-minute period. If this reading has not changed more than 0.25 percent from the initial meter reading, record this second reading as the final meter reading.

If the second reading has changed by more than 0.25 percent from the initial meter reading, record this (second) reading as the new initial reading and repeat the one minute turning and rolling process. Once again, set the meter upright and loosen the top and allow it to stand while the air rises to the top and the liquid level stabilizes. The liquid level is considered stable when it does not change more than 0.25 percent within a two-minute period. If this reading has not changed more than 0.25 percent from the new initial meter reading, record this second reading as the final meter reading. If this reading has changed by more than 0.25 percent, discard the test and start the test again using more alcohol than was used initially.

<u>Step 5 (disassembling the meter):</u>

Disassemble the meter, and empty the contents of the bowl. If any portions of undisturbed, tightly packed concrete remain in the bowl, the test is invalid and must be performed again.

Since you don't want to have to run the test more than once, it is very important to invert and agitate then rock and roll the meter as well as possible to ensure that no concrete is stuck in the bottom of the bowl.

Step 6 (calculating the air content):

You are now ready to calculate the air content of the sample. When less than 2.5 pints (40 ounces) of alcohol is used, the final meter reading is the actual air content of the concrete unless water was added in Step 4. If it was necessary to add calibrated cups of water in Step 4, add the number of cups recorded to the final meter reading to obtain the actual air content. When 2.5 pints (40 ounces) or more of alcohol is used, subtract the correction from Table 1 from the final meter reading to obtain the actual air content. Record the actual air content to the nearest 0.25 percent air.

TABLE 1

Amount of 70% Isopropyl Alcohol Used		Correction (Amount to be Subtracted From Final Meter Reading)
Pints (pt)	Ounces (oz)	
0.5	8	0.0
1.0	16	0.0
1.5	24	0.0
2.0	32	0.0
3.0	48	0.3
4.0	64	0.6
5.0	80	0.9

Note: Use linear interpolation to obtain a correction factor if the quantity of alcohol used falls between the amounts listed in Table 1.

EXAMPLE:

You have properly sampled the concrete, loaded, rodded, tapped, and struck off the bowl. You then added enough water and alcohol (16 ounces were added in this example) to bring the water level up to the zero mark in the calibrated neck portion of the meter. Now you invert and agitate the meter for at least 45 seconds and turn and roll the meter for one minute.

Now, you sit the meter upright and loosen the cap. The liquid level is below the 9% mark and is not visible in the calibrated neck of the meter. Therefore, you need to add water (in calibrated cups) to bring the liquid level up into the neck. After adding three calibrated cups of water to the meter, you look at the calibrated neck of the meter and can clearly distinguish a liquid level, and there is less foam above the liquid level than two graduated divisions in the neck. Record the addition of the three calibrated cups of water. At this point, the liquid level is at 6.5%. After one minute, the level has dropped to 6.80%, and after two minutes, it has dropped to 6.90%. Since the liquid level has dropped more than 0.25% (it has actually dropped 0.40%), you must wait longer for the liquid level to stabilize. After three minutes, the liquid level is at 7.00%. Now, since the liquid level hasn't changed more than 0.25% in the last two minutes (it's only changed by 0.20%) and it took less than six minutes to get two readings that didn't change by more than 0.25%, the liquid level is considered to be stable. Record 7.00% as the initial meter reading.

You now tighten the cap and repeat the one minute turning and rolling process. Then sit the meter upright and loosen the cap. You look at the calibrated neck of the meter and can clearly distinguish a liquid level, and there is less foam above the liquid level than two graduated divisions in the neck. At this point, the liquid level is at 7.20%. After two minutes, the level has dropped to 7.40%. Since the liquid level hasn't changed more than 0.25% in the last two minutes (it's only changed by 0.20%) and it took less than six minutes to get two readings that didn't change by more than 0.25%, the liquid level is considered to be stable. Since this second reading of 7.40% has changed by more than 0.25% from the initial meter reading (it's actually changed by 0.40% from the initial meter reading of 7.00%), you must repeat the one minute turning and rolling procedure. Record 7.40% as the new initial meter reading.

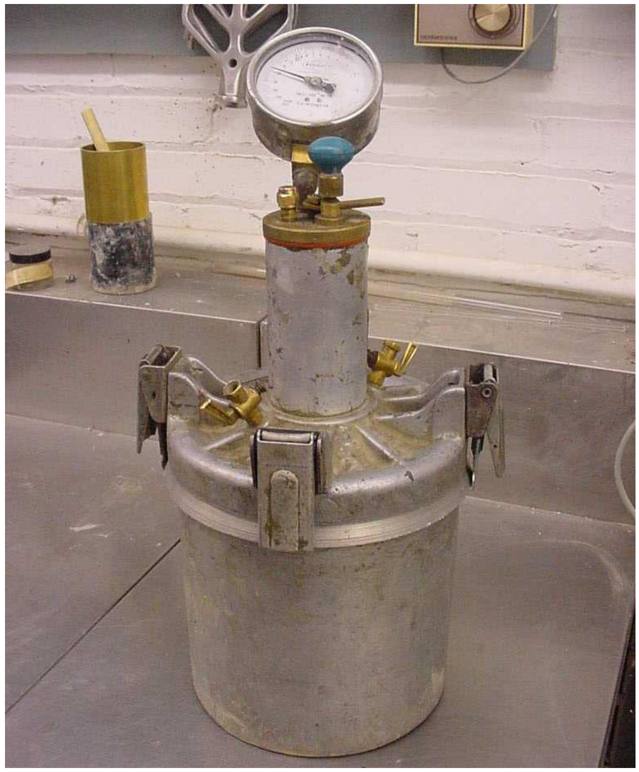
You now tighten the cap and repeat the one minute turning and rolling process. Then sit the meter upright and loosen the cap. You look at the calibrated neck of the meter and can clearly distinguish a liquid level, and there is less foam above the liquid level than two graduated divisions in the neck. At this point, the liquid level is at 7.50%. After two minutes, the level is still at 7.50%. Since the liquid level hasn't changed more than 0.25% in the last two minutes (it hasn't changed at all) and it took less than six minutes to get two readings that didn't change by more than 0.25%, the liquid level is considered to be stable. Since this reading (7.50%) changed by less than 0.25% from the new initial reading of 7.40% (it only changed by 0.10%), record 7.50% as the final meter reading.

You now disassemble the meter and empty out the bowl. When you do this, you find that no concrete is stuck inside the bowl, so therefore, this was a valid test. You are now ready to calculate your air content.

Since less than 40 ounces of alcohol were used, no correction needs to be applied from Table 1. Since it was necessary to add calibrated cups of water to initially bring the liquid level into the neck, this must be accounted for. Three calibrated cups of water were added, so we add this number to the final meter reading to obtain the actual air content. Our actual air content is then 10.50% (7.50% final meter reading + 3 calibrated cups of water = 10.50%).

SECTION 5.3.2

AIR CONTENT OF FRESHLY MIXED CONCRETE
BY THE PRESSURE METHOD
AASHTO T 152



This test method describes the procedure for determining the air content of freshly mixed concrete by observing the changes in volume caused by changes in pressure. The standard procedure for conducting this test is AASHTO T 152. This method is intended for use with concrete and mortar made with relatively dense natural aggregates. It is not to be used with concrete made with lightweight aggregates, air-cooled blast-furnace slag, or aggregates of high porosity.

The pressure method of determining air content is based on Boyle's Law, which states: "at a constant temperature the volume of a given quantity of any gas varies inversely as the pressure to which the gas is subjected".

There are two types of air meters recognized by AASHTO. These are designated as Meter Type A and Meter Type B in AASHTO T 152 and are defined as follows:

Type A is a meter in which water is added to a predetermined height above a sample of concrete of known volume. Then the air pressure is released and forces the water into the air voids in the concrete. The amount of air in the concrete is determined by observing the reduction in the water level. This reduction in water level is calibrated in terms of the percent air in a concrete sample.

Type B equalizes a known volume of air at a known pressure in a sealed air chamber. When this air is released into the concrete sample, a pressure gauge indicates the percent air in the concrete. The pressure gauge is calibrated in terms of percent air for the observed pressure at which pressure equalization takes place.

For the purposes of this course and any test (written or practical), all questions about the test method for determination of air content by a pressure meter will pertain to the Type B pressure meter. You will still be required to know the differences between the two meters.

Now see if you can answer the following question:

1. Concrete is made with several different types of aggregates. Which of the following two groups are not recommended for use in the pressure meter?

1.1 Gravel or limestone.

1.2 Slag or other lightweight aggregates.

For the answers, turn to the next page.

1.1 WRONG ANSWER. Gravel and limestone aggregates may be tested in the pressure meter. Remember we said that concrete using slag and lightweight aggregates must be tested by the volumetric method.

1.2 CORRECT ANSWER.

Equipment - The equipment needed for this test consists of:

1. Air Pressure Meter Assembly - Type B.
2. Calibration Vessel (see AASHTO T-152).
3. Tamping Rod (5/8 inch diameter, 16 to 24 inches long, and with a rounded hemispherical tip)
4. Mallet - A rubber or rawhide head with a weight of approximately 1.25 $\pm$ 0.50 lb. for use with measures of 0.5 ft^3 or smaller. A rubber or rawhide head with a weight of approximately 2.25 $\pm$ 0.50 lb. for use with measures larger than 0.5 ft^3.
5. Strike-off Bar - A flat straight bar of steel or other suitable metal at least 1/8 inch thick and ¾ inch wide by 12 inches long.
6. Scoop
7. Measure For Water - having the necessary capacity to fill the indicator.
8. Rags
9. Rubber Syringe
10. Vibrator (for low slump concrete) – Vibrator frequency shall be at least 7000 vibrations per minute (115 Hz) while the vibrator is operating in the concrete. The diameter of a round vibrator shall be no more than one-fourth (25%) of the diameter of the bowl. The combined length of the vibratory shaft and the vibrating element shall be at least 3 inches greater than the depth of the section being vibrated.

Calibration of Apparatus

Calibration of Type B meters should be conducted in accordance with the procedures outlined in AASHTO T-152. **The calibration tests described in T-152 should be made as frequently as necessary and at intervals not to exceed three months to ensure that the correct air contents are being indicated on the pressure gage for the Type B meter.**

There are several factors that will affect the air meters. Rough handling will affect the calibration of air meters. Changes in barometric pressure will affect the calibration of a Type A meter, but not Type B meter. The Type A meter will also be affected by a change in elevation of 600 feet or more from the location of the last calibration. A build up of hardened concrete inside the measuring bowl of the meter will affect the calibration of the air meter.

Sample

A representative sample of concrete shall be obtained in accordance with Chapter 4 of this manual (AASHTO R 60). The air test must be started within 5 minutes after obtaining the final portion of the composite sample.

Procedure - Aggregate Correction Factor

When determining air content by the pressure method we must take into account the porosity of the aggregate contained in our concrete sample. The actual air content of our sample will be lower than that indicated by this air test if we do not subtract the air contained in the pores of the aggregate. Thus, the first step in our procedure is to determine the aggregate correction factor for the aggregate being used in the concrete mix. AASHTO T-152, Section 6, outlines the procedure to be used for this determination. The aggregate correction factor is determined by applying the calibrated pressure to a sample of coarse and fine aggregates which are in the same amount, proportions, and approximate moisture condition as those occurring in the concrete sample being tested (basically an air test on a sample of aggregates with the same proportions as those in the concrete being tested).

This test can be easily made and must not be ignored. The correction factor will stay fairly constant for a particular aggregate and need only be checked occasionally. The determination of the aggregate correction factor is usually performed at the plant or performed by the aggregate supplier. **The aggregate correction factor is required to be noted on Attachment 3 of the Concrete Supplier's approved mix design, and it is not a determination that will be made in the field.** If this information is not on the batch ticket, it is the PCC Inspector's responsibility to contact the appropriate source and get the aggregate correction factor.

Procedure - Placement, Consolidation and Strike-Off

After the sample has been obtained and re-mixed we are ready to start the test.

The testing equipment should be damp, so a damp rag is used to dampen the bowl, rod and scoop. Place concrete in the measuring bowl until the bowl is one-third full. Consolidate this first layer by rodding the concrete 25 times, uniformly distributing the strokes around the bowl to cover the entire cross-section. Do not strike the bottom of the bowl forcibly with the tamping rod.

Tap the sides of the bowl (10 to 15 times) with the mallet until the cavities left by rodding are leveled out and no large bubbles of entrapped air appear.

Add the second layer of concrete to the bowl until the measure is two-thirds full. Rod this layer 25 times in the same manner as the first layer. The tamping rod should only penetrate the surface of the first layer about one inch. Like the first layer, tap the sides of the bowl with the mallet (10 to 15 times) until no large voids appear.

Add the final layer of concrete to the bowl, taking care not to overfill. Rod and tap this layer the same as the first two layers.

Vibration is another method of consolidation that is sometimes required for this test. Any concrete with a slump greater than 3 inches must be consolidated by rodding. Concrete with a slump of 1 to 3 inches may be rodded or vibrated. Concrete with a slump of less than 1 inch must be consolidated by vibration.

When consolidating concrete by vibration, the concrete is placed into the measuring bowl until it is half full. The vibrator is then inserted into this layer at three different locations. Be careful not to let the vibrator rest on the sides or the bottom of the measuring bowl. Now, fill the remainder of the measuring bowl to slightly above the top with concrete. The vibrator is then inserted into this layer at three different locations. Take care in withdrawing the vibrator to ensure that no air pockets are left in the concrete.

Now, after consolidation is completed (no matter which method of consolidation was used), the concrete sample is ready for strike off. Ideally, the concrete level should be about 1/8 inch above the top of the bowl prior to strike off. The surface of the concrete should be struck off in a sawing motion across the top flange or rim of the bowl with the steel strike off bar. After strike off, the bowl should be just level full. Clean the flange of the bowl and the cover assembly to ensure that a pressure-tight seal is obtained when the cover is clamped in place. At this point, the test procedure varies for Type A or B meters. We will only be discussing the procedure for the Type B Meter. Both procedures are detailed in AASHTO T 152.

Procedure - Type B Meter Test Method

Assemble the apparatus, being careful that all clamps are tight and a pressure-tight seal is obtained. Close the main air valve between the air chamber and the measuring bowl and open both petcocks. Using the syringe, inject water through one petcock until water begins to come out the opposite petcock. You may have to rock or tap the meter gently to expel all of the air. Close the air-bleeder valve on the air chamber and pump air into the chamber until the gage needle is on the initial pressure line (this point was determined when the meter was calibrated). Wait several seconds to allow the air in the gage to cool. You may have to pump or bleed off air as necessary until the needle stabilizes at the initial pressure point, tapping the gage lightly by hand. Close the petcocks, and open the main air valve between the air chamber and the measuring bowl. Smartly tap the side of the bowl with the mallet to relieve any restraints, and then tap the gage lightly by hand to stabilize the gage hand. Read the percentage of the air on the dial of the pressure gage to the nearest 0.10 percent. The actual air content of the concrete is the dial reading minus the aggregate correction factor. For example, if the gage reading is 7.1 percent and the aggregate correction factor is 0.3 percent, the actual air content of the concrete is 6.8 percent. The aggregate correction factor will change depending on the types and sources (for both fine and coarse aggregate) of aggregate being used in the mix.

Now see if you can answer the following:

2. It is extremely important that the exact initial pressure is obtained on the gauge, before being released into the contents of the bowl. After the hand on the dial is stabilized, the pressure is too high. How would you adjust the pressure to the desired amount?

2.1 By bleeding off the excess pressure by opening the petcocks.

2.2 By bleeding off the excess pressure by opening the air-bleeder valve.

For the answers, turn to the next page.

2.1 NO. Remember the air pressure is in a compression chamber and can't be released by opening the petcocks. Also, remember that as the meter is being pumped up to the initial pressure, the petcocks should already be open. If the petcocks are open during this phase of the test (as they should be), you will be able to detect any leaks in the air chamber. The petcocks are then closed before the pressure is released from the air chamber into the bowl.

2.2 YES. You are correct.

SECTION 5.4

UNIT WEIGHT AND YIELD OF CONCRETE
AASHTO T 121

One of the characteristics of Portland cement concrete that can be used as a very useful tool is the unit weight (weight per cubic foot). Unit weight (or weight per unit volume) is generally expressed as pounds per cubic foot and is written as lb/ft^3.

In this chapter, we will study the procedure used to determine the unit weight of concrete, which is then used to calculate the batch volume. The standard procedure for conducting this test is AASHTO T 121. This test method uses a measure of a known volume to determine the unit weight of concrete. The size of our measures is governed by the **Nominal Maximum Size** of the coarse aggregate in the concrete mix (see AASHTO T 121, Table 1).

Table 1

Nominal Maximum Size of Coarse Aggregate		Capacity of Measure	
mm	inches	L	ft^3
25.0	1	6	0.2
37.5	1.5	11	0.4
50	2	14	0.5
75	3	28	1.0
112	4.5	70	2.5
150	6	100	3.5

Maximum Size vs. Nominal Maximum Size Aggregate

Often there is confusion surrounding the term “maximum size” of aggregate. The maximum size of an aggregate is the smallest size sieve through which **all** aggregate must pass (100% passing). The Nominal Maximum Size of an aggregate is defined as the smallest size sieve through which the majority of the aggregate must pass (typically 85% to 95% passing). Or, worded another way, the Nominal Maximum Size of an aggregate may be defined as the largest sieve size on which any material may be retained.

For example: An AASHTO #57 coarse aggregate has a maximum size of 1.5-inches, and it has a Nominal Maximum Size of 1-inch.

If nothing else were known about the test method, how would you solve the following problem?

1. It was determined, by using a 0.5 ft^3 box, that the concrete sample in the box had a weight of 75 lb. What would be the weight of 1.0 ft^3 of concrete?

Answers:

A. 150 lb/ft^3

B. 75 lb/ft^3

Turn to the next page for the answers.

A. Yes. You are correct.

$$\frac{75\ \text{lb}}{0.5\ \text{ft}^3} = 150\ \text{lb/ft}^3$$

Unit weight (expressed as lb/ft^3) is a measure of how much 1.0-ft^3 of concrete weighs.

B. No. The weight, 75 lb. is the amount of concrete in the 0.5 ft^3 box, and we were asked to find the weight for 1.0 feet of concrete.

Therefore:

If 0.5 ft^3 concrete has a weight of 75 lbs., what would be the weight of one cubic foot?

One cubic foot has twice the amount of our original volume, so 75 lbs. times two (or 75 lbs. Divided by ½).

Answer: 150 lb/ft^3

One simple way to remember how to get unit weight is to work with the units for unit weight (lb/ft^3). By looking at the units, we see that the weight (lbs.) must be divided by the volume (ft^3) in order for us to get the correct units in the answer. So, to find unit weight, simply divide the weight of an object by the volume that it occupies.

It is also important to remember that when finding the unit weight of concrete, the concrete is weighed while in a container. Since you are only concerned with the weight of the concrete, you must first subtract the weight of the container from the total weight.

Equipment - The equipment needed to determine the unit weight of concrete is as follows:

1. Measure of sufficient size based on NMS of aggregate (Table 1 of AASHTO T 121)
2. Scoop
3. Tamping Rod – 5/8 in. diameter, 16 to 24 inches in length, having the tamping end rounded to a hemispherical tip the diameter of which is 5/8 in.
4. Strike-Off Plate - Flat rectangular metal plate at least 1/4 in. thick or a glass or acrylic plate at least 1/2 in. thick with a length and width at least 2 in. greater than the diameter of the measure being used.
5. Rubber Mallet weighing approximately 1.25 $\pm$ 0.50 lb. for use with measures of 0.50 ft^3 or smaller and a mallet weighing approximately 2.25 $\pm$ 0.50 lb. for use with measures larger than 0.50 ft^3.
6. Balance (scale) – accurate to within 0.3 percent of the test load at any point within the range of use.
7. Rags or Damp Sponge
8. Vibrator (for low slump concrete) - the frequency of vibration shall be 7000 vibrations per minute (117 Hz) or greater while in use. The outside diameter of the vibrating element shall be at least ¾ inch and not greater than 1.5 inches. The shaft shall be at least 24 inches long.

Calibration of Unit Weight Measure

AASHTO T 121 is somewhat similar to the previous exercise but is a more accurate way to determine the unit weight of concrete. In order to determine if the measure has any defects that would alter its volume from the nominal value, we have to develop a correction or multiplying factor to compensate for this. AASHTO T 121 refers us to AASHTO T 19 for calibrating the measure and determining this correction factor.

The correction factor is determined by filling the appropriate measure with water that is at room temperature. If you use some form of grease around the top of the measure and lay a glass plate over it with just a small corner open, you will be able to fill the measure to capacity with a syringe and avoid any spilling. The weight of the measure, glass plate, and grease must be determined prior to filling the measure so that you can subtract their weight from the total weight of the measure when fully filled with water. This will, of course, give you the weight of water in the measure. Finally, when filling the measure, the water temperature must be determined. Table 3 of AASHTO T-19 gives us values for the weight of a cubic foot of water at a given temperature. We will need this table to calculate the correction factor for the measure (unit weight bucket).

Unit Weight Measures shall be recalibrated at least once a year or whenever there is reason to question the accuracy of the calibration. This calibration includes the calculation of the correction factor.

Let's work now on an example and calculate the correction factor for a given measure.

Example:

Suppose we have determined a 0.5 ft^3 (nominal volume) measure to contain 30.78 lb. of water at a temperature of 70 °F. Table 3 of AASHTO T 19 shows that at 70 °F, 1.0 ft^3 of water has a weight of 62.301 lb.

Our factor is now obtained simply by dividing the weight of 1.0 ft^3 of water at 70 °F (62.301 lb/ft^3) by the weight of water required to fill the measure (which we determined to be 30.78 lb.).

$$\text{Therefore: } \frac{62.301\ lb/ft^3}{30.78\ lb.} = \frac{2.0241}{ft^3}$$

Where 2.0241 is our correction factor and the number that we would use to multiply. This tells us that the volume of our measure is slightly less than what we thought initially.

Notice that the units for the correction factor are ($1/ft^3$). When this correction factor is multiplied by the weight of the concrete (lbs.), the resulting units will be (lb/ft^3). So, once again we see that by keeping track of the units, you can be sure that your answer comes out correctly.

One way to think of the correction factor is:

$$\text{Correction Factor} = \frac{1}{\text{Actual Volume}}$$

or:

$$\text{Actual Volume} = \frac{1}{\text{Correction Factor}}$$

Therefore, if we had a unit weight bucket with an **actual volume** of exactly 1/3 ft^3, the correction factor would be 3.0000 (1 divided by 1/3 ft^3). But, even if you are using what you think is a 1/3 ft^3 unit weight bucket, the actual volume may be slightly more or less than 1/3 ft^3 because of wear or concrete buildup in the bucket.

Likewise, if we had a unit weight bucket with a correction factor of 3.0750, the actual volume of the bucket would be 0.3252 ft^3 (1 divided by 3.0750).

This is why the correction factor is used. Because even though you are using a unit weight bucket of a certain (nominal) volume (1/3 ft^3, 0.4 ft^3, 1/2 ft^3, etc.), the **actual volume** of the unit weight bucket may not be 1/3 ft^3, 0.4 ft^3, 1/2 ft^3, etc. This is why we must periodically (at least annually) calibrate the bucket and assign it a correction factor.

Problem:

2. Using a nominal 0.4 ft^3 measure, it was found that 25.12 lb. of water at 60 °F was required to fill the measure. (Table 3 of AASHTO T 19 indicates that the density of water at 60 °F is 62.366 lb/ft^3). Calculate the correction factor.

Which is correct?

2.1 2.483

2.2 0.403

Turn to the next page for the answers.

2.1 Yes. You are correct.

2.2 No. Divide the weight of water at 60 °F by the determined weight.

$$\text{Factor} = \frac{62.366 \text{ lb/ft}^3}{25.12 \text{ lb}} = 2.483/\text{ft}^3$$

Now that the correction factor for the measure has been determined, we can use the measure along with our correction factor in determining the unit weight of concrete.

Sample

Obtain the sample of fresh concrete as described in Chapter 4 of this manual (AASHTO R 60). Remix the sample with the scoop enough to ensure that the sample is uniform in appearance.

Procedure

Weigh and record the weight of the empty measure. Then wipe out the inside of the measure with a damp rag or sponge. Using the scoop, fill the measure with the sample to approximately 1/3 of its volume, and uniformly distribute the concrete in the measure. Rod the layer 25 times when the measure is 0.5 ft^3 or smaller (50 times if the measure is larger). Distribute the strokes uniformly over the cross-section of the measure. Do not permit the rod to forcibly strike the bottom of the measure. Tap the side of the measure with the appropriate rubber mallet (10 to 15 times) to cause the concrete to flow into the depressions left by the rod, thus eliminating the possibility of large air bubbles being entrapped while filling the measure. Add concrete again to the measure in the manner just described until it is approximately 2/3 full. Rod the layer in the same manner as the first layer, except that the rod should just penetrate the underlying layer about one inch. Then again tap the side of the measure (10 to 15 times) with the rubber mallet. Finally add concrete to the measure, in the same manner as previous layers, until it protrudes above the measure approximately 1/8 inch. Rod the layer in the manner described when the measure was 2/3 full and then tap the side of the measure 10 to 15 times.

Vibration is another method of consolidation (instead of rodding) that is sometimes required for this test. Any concrete with a slump greater than 3 inches must be consolidated by rodding. Concrete with a slump of 1 to 3 inches may be rodded or vibrated. Concrete with a slump of less than 1 inch must be consolidated by vibration.

When consolidating concrete by vibration, the concrete is placed into the measure until it is half full. The vibrator is then inserted into this layer at three different locations. Be careful not to let the vibrator rest on the sides or the bottom of the measuring bowl. Now, fill the remainder of the measuring bowl to slightly above the top with concrete. The vibrator is then inserted into this layer (penetrating the underlying layer approximately one inch) at three different locations. Take care in withdrawing the vibrator to ensure that no air pockets are left in the concrete.

After the last layer has been consolidated (by either rodding or vibration), the measure should not contain a substantial excess or deficiency of concrete. An excess of concrete protruding approximately 1/8 inch above the top of the mold is ideal. A small quantity of concrete may be added to correct a deficiency. If there is a large excess of concrete after consolidation, remove a representative portion of the excess concrete with a scoop or trowel immediately after consolidation and before strike-off. We must now strike off the excess concrete until the measure is exactly full.

Place the strike-off plate flat on the top surface of the measure so that it covers about two-thirds of the surface. Applying enough pressure to the plate to keep it resting flat on the lip of the measure, withdraw the plate using a sawing motion back across the area.

Now place the plate flat on the top surface of the measure so it covers the two-thirds of the surface we just worked on, and advance the plate in a sawing motion across the whole surface of the measure. Once the entire surface of the measure has been struck off with the plate in the flat position, you may tilt the plate and draw the edge lightly across the top surface several times to smooth the surface, if needed. Clean all concrete from the outside of the measure with a damp cloth or sponge. Place the filled measure on the scale and determine the total weight of the measure plus the concrete. Then subtract the weight of the empty measure from the total weight (measure filled with concrete) to obtain the weight of concrete.

The unit weight of the concrete is now obtained by multiplying the weight of concrete in the container by the correction factor of the measure.

An example of a unit weight calculation is as follows:

Measure correction factor	= 3.0175
Weight of Empty Measure	= 16.24 lb.
Weight of Concrete and Measure	= 63.57 lb.
Unit Weight	= 142.82 lb/ft^3

Weight of Concrete and Measure – Weight of Empty Measure =

63.57 lb. – 16.24 lb. = 47.33 lb. (Weight of the Concrete)

Weight of the Concrete x Measure Correction Factor = Unit Weight

47.33 lb. X 3.0175 = 142.82 lb/ft^3 = Unit Weight of the Concrete

Now that the measure calibration and the test procedure have been described it is time for you to demonstrate your understanding of the procedure by solving the following problem:

PROBLEM: While calibrating a 0.5 ft^3 unit weight measure and conducting the unit weight test, the following data was collected:

Weight of water at 75 °F in measure	= 31.2 lb.
Weight of empty measure	= 22.50 lb.
Total weight of the measure and concrete	= 99.32 lb.

What is the Unit Weight of the concrete?

A. 153.29 lb/ft^3

B. 142.63 lb/ft^3

Turn to the next page for the answers.

A. Yes. You are correct. The calculation is as follows:

From AASHTO T 19 Table 3: Density of water @ 75 °F is: 62.261 lb/ft^3

$$\text{Correction Factor} = \frac{\text{Density of Water}}{\text{Weight of Water in Measure}}$$

$$= \frac{62.261\ lb/ft^3}{31.2\ lb} = 1.9955/ft^3$$

(Weight of Concrete and Measure - Weight of Measure) x (Correction Factor) = Unit Weight of Concrete (lb/ft^3)

(99.32 lb. – 22.5 lb.) x ($1.9955/ft^3$) = 153.29 lb/ft^3

B. NO. You are incorrect. Recheck calculations and review this section. The solution is shown above.

The unit weight test is performed in order to obtain additional information regarding the concrete. The most important use of the unit weight test is to determine the yield of concrete being produced. Yield is the actual volume of concrete produced per batch and should be equal to the design value. Concrete is batched by weight (weight of aggregates, weight of cement, weight of water, etc.). When concrete is ordered, though, it is ordered by volume (cubic yard, etc.). There is a relationship between weight and volume that is governed by specific gravity. We will not go into that relationship here. When a yard of concrete is batched, all of the materials are batched by weights that should total up to a weight that is equal to one cubic yard of concrete. You may think, based on the batch weights, that one cubic yard of concrete is being produced. But, because of real world factors (moisture in the aggregates, an inaccurate specific gravity, and many other factors that may change even during a single day of production), slightly more or slightly less than one cubic yard may actually be produced. This is the reason for the yield calculation (which we need the unit weight test to calculate). The yield test will tell you whether or not you are producing the target volume of batched concrete. Once the yield is determined, the plant can make adjustments so that the exact desired volume of concrete is produced.

The yield is computed by dividing the total weight of material in the batch by the unit weight of the concrete (determined from the unit weight test).

$$\text{Batch volume} = \frac{\text{Total Weight of Material Batched (lb)}}{\text{Unit Weight of Concrete Sample (lb/ft}^3\text{)}}$$

Example:

A concrete plant receives an order for one cubic yard of concrete. They weigh and batch all of the materials that are required to produce one cubic yard of concrete (according to their approved mix design). The concrete being batched has a weight of 3687 lb. A unit weight test on a sample of the fresh concrete indicated a unit weight of 138.61 lb/ft^3. What is the yield of concrete being produced?

$$\text{Batch Volume} = \frac{3687 \text{ lb}}{138.61 \text{ lb/ft}^3} = 26.60 \text{ ft}^3$$

We can see by this calculation that slightly less than one cubic yard (27.0 ft^3 = 1.0 yd^3) is being produced.

Problem:

The following scale weights are being used to batch 4.0 cubic yards (108.0 cubic feet) of concrete:

Cement	2444 lb.
Coarse Aggregate	7290 lb.
Water	1100 lb.
Fine Aggregate	5020 lb.

A unit weight test conducted on a sample of the concrete revealed the following data:

Measure Factor: 2.974

Weight of Empty Measure: 14.37 lb.

Weight of Concrete and Measure: 61.38 lb.

What is the yield of the concrete being produced?

A. 3.85 yd^3

B. 4.20 yd^3

Turn to the next page for the answers.

A. NO. You are wrong. Recheck calculations and review procedure for determining unit weight and yield. If you still have problems, see the solution on the next page.

B. YES. The yield is 4.20 yd^3 and is determined in the following manner:

1. Weight of concrete in measure = 61.38 lb. – 14.37 lb. = 47.01 lb.

2. Unit weight = weight of concrete in measure x measure factor
   = 47.01 lb. x 2.9742 = 139.82 lb/ft^3

3. Add up all of the batch weights:
   2444 lb. + 7290 lb. + 1100 lb. + 5020 lb. = 15854 lb.

4. Yield = the total batch weight divided by the unit weight:

$$\frac{15854 \text{ lb.}}{139.82 \text{ lb/ft}^3} = 113.39 \text{ ft}^3$$

5. This yield (batch volume) can then be converted to cubic yards. Since 1.0 yd^3 = 27.0 ft^3, we can convert 113.39 ft^3 to cubic yards in the following manner:

$$113.39 \text{ ft}^3 \times \frac{1.0 \text{ yd}^3}{27.0 \text{ ft}^3} = 4.20 \text{ yd}^3 \text{ (this is the yield)}$$

We will now briefly discuss relative yield. Relative yield is defined as the ratio of the actual volume of the concrete obtained (the volume calculated in your yield test) to the volume as designed for the batch.

Thus, for the previous example, we would calculate the relative yield as follows:

$$\text{Relative Yield} = \frac{4.20\ \text{yd}^3}{4.0\ \text{yd}^3} = 1.05$$

or:

$$\text{Relative Yield} = \frac{113.39\ \text{ft}^3}{108.0\ \text{ft}^3} = 1.05$$

You will notice that there are no units for relative yield because it is a ratio. For this reason, it does not matter if you compute the relative yield by using cubic feet or cubic yards.

A relative yield value greater than 1.00 indicates an excess of concrete being produced. Whereas a relative yield value less than 1.00 indicates that there is less concrete being produced than the design volume.

Yield and relative yield are both very important because they are indicators of your <u>actual</u> cement factor. Class B concrete (3000 psi) is usually batched with 6 bags (564 lbs.) of cement. If when batching one yard of Class B concrete (using 564 lbs. of cement), the results of your yield test indicate that 27.5 ft^3 of concrete are actually being produced (or a relative yield of 1.02), this is an over-yield. This means that you are actually producing more than one yard of concrete with the same amount of cement that should be used in exactly one yard of concrete. So instead of having a cement factor of 564 lbs. per yard (27.0 ft^3), you actually have a cement factor of 564 lbs. per 1.02 yards (27.5 ft^3). By looking at this, we can see that when you have an over-yield, there is actually less cement per cubic yard (your cement factor is reduced). This can be seen mathematically on the next page.

Cement Factor for 1.0 yards (27.0 ft^3) of Class B concrete:

$$\frac{564\,lbs.}{1.0\,yards} = 564 \text{ lb/yard}$$

Cement Factor for 1.02 yards (27.5 ft^3) of Class B concrete:

$$\frac{564\,lbs.}{1.02\,yards} = 553 \text{ lb/yard}$$

(553 < 564, therefore this is a lower cement factor)

In this example of an over-yield, there is only 98% (553/564=0.98 or 98%) as much cement in the mix as there needs to be.

The reverse is also true for an under-yield. When you have an under-yield, there is more cement per yard (or a higher cement factor) than your design yield. This is why an under-yield is better (from a strength standpoint) than an over-yield.

T602
Rev 8-02

WEST VIRGINIA DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION
WEIGHT PER CUBIC FOOT AND YIELD OF CONCRETE

CONCRETE PLANT	
SOURCE CODE	
MIX DESIGN NO.	
PROJECT	

DATE	
CONCRETE CLASS	
MATERIAL CODE	
INSPECTOR	

UNIT WEIGHT			
	BATCH 1	**BATCH 2**	**BATCH 3**
A. WEIGHT OF EMPTY MEASURE (lb)			
B. WEIGHT OF MEASURE + CONCRETE (lb)			
C. WEIGHT OF CONCRETE (B – A) (lb)			
D. MEASURE CALIBRATION FACTOR (1/ft^3)			
W. UNIT WEIGHT OF CONCRETE (C x D) (lb/ft^3)			

TOTAL WEIGHT OF ALL MATERIALS BATCHED			
	BATCH 1	**BATCH 2**	**BATCH 3**
E. WEIGHT OF CEMENT (lb)			
F. WEIGHT OF MINERAL ADMIXTURE (lb)			
G. WEIGHT OF WATER (lb)			
H. WEIGHT OF COARSE AGGREGATE (lb)			
I. WEIGHT OF FINE AGGREGATE (lb)			
W_1. TOTAL BATCH WEIGHT (E +F + G + H + I) (lb)			

YIELD			
	BATCH 1	**BATCH 2**	**BATCH 3**
Y_d. VOLUME OF CONCRETE WHICH THE BATCH WAS DESIGNED TO PRODUCE (yd^3)			
Y. ACTUAL VOL OF CONCRETE PRODUCED PER BATCH (YIELD=W_1/27W) (yd^3)			
R_Y. RELATIVE YIELD (RATIO OF ACTUAL VOL TO DESIGN VOL) (Y/Y_d)			

ACTUAL YEILD (AVERAGE OF THREE BATCHES) = ($R_{Y\ (BATCH\ 1)}$ + $R_{Y\ (BATCH\ 2)}$ + $R_{Y\ (BATCH\ 3)}$) ÷ 3

ACTUAL YEILD = (____________ + ____________ + ____________) ÷ 3 = [ ]

NOTE: A VALUE FOR THE ACTUAL YIELD (OR RELATIVE YIELD) GREATER THAN 1.00 INDICATES AN EXCESS OF CONCRETE BEING PRODUCED (AND THEREFORE A LOWER CEMENT FACTOR) WHEREAS A VALUE LESS THAN THIS INDICATES THE BATCH TO BE SHORT OF ITS DESIGNED VOLUME (AND THEREFORE A HIGHER CEMENT FACTOR).

SECTION 5.5

COMPRESSIVE STRENGTH
AASHTO T 22 and AASHTO T 23

The compressive strength of concrete is expressed as the load (in pounds) per unit area (square inches) that would be necessary to crush the concrete. The common procedure used to measure the compressive strength of concrete is to place a sample of the concrete (called a test cylinder) in a testing machine and find the force required to crush it.

Another method for determining the strength of pavement concrete (see section 501 of the WVDOH Standard Specifications) is the testing of flexural strength test specimens. We will not discuss this method in this manual, but the procedure for the fabrication of these specimens (beams) is detailed in AASHTO T 23. The procedure for testing these specimens is detailed in AASHTO T 97.

The most accurate results of the compressive strength test are obtained when the test specimens are in the form of a cylinder whose height is twice the diameter. Also, the diameter of the test specimen should be at least three times the size of the largest aggregate particle in the concrete to be tested. In order to standardize the dimensions of test cylinders and satisfy the above requirements, cylinders with a 6-inch diameter and 12-inch height or cylinders with a 4-inch diameter and 8-inch height are used. WVDOH specifications allow the use of either 6" x 12" or 4" x 8" cylinders for concrete testing, but in order to use 4" x 8" cylinders, certain requirements, outlined in MP 711.03.23, must be met. AASHTO T 23 details the procedure for making and curing compressive strength cylinders.

Test cylinders are normally tested for three reasons. One is to check the adequacy of the laboratory mixture proportions for strength. The second reason is for use as the basis of acceptance. The third reason is to determine when a structure may be put in service or when forms could be removed.

AASHTO T 22 details the procedure for determining the compressive strength of the cylinders (testing cylinders).

Each mold used to make a 6" x 12" cylinder holds approximately 0.2 ft^3 or about 30 lbs. of concrete. In order for a test specimen made from a very small amount of concrete to accurately represent up to 100 cubic yards of concrete, the standard procedures for sampling, molding, curing, and testing the test specimens must be followed exactly. Also, the standard procedure must be followed so that the test result can be validly compared to other tests.

The standard cylinder molds must be made of plastic, steel, cast iron, or other non-absorbent material, that is non-reactive when placed in contact with the concrete. The most common mold is a single use mold made of plastic.

Sample

The sample of fresh concrete used to make test specimens must be representative of the concrete that is used in the structure. Obtain the sample of fresh concrete as described in Chapter 4 of this manual (AASHTO R 60). Remix the sample with the scoop enough to ensure that the sample is uniform in appearance. The sample shall consist of at least one cubic foot of concrete, and after it is collected, it is to be taken to the place where the specimens are to be molded. It shall be protected from sunlight and wind during the period between sampling and using. The molding of test specimens must be started within 15 minutes after the sample is taken.

DOH Specification 601.4.4 specifies that the compressive strength test shall consist of a set of 3 specimens. The compressive strength of the 3 specimens is averaged and this average is considered to be the compressive strength of the sample.

There is a very important exception to this. Section 601.4.4 of the standard specifications states: "The test shall be the average of the three specimens, except that if one specimen shows manifest evidence of improper sampling, molding, or testing, it shall be discarded and the remaining two strengths averaged. Should more than one specimen representing a given test show definite defects due to improper sampling, molding, or testing, the entire test shall be discarded." This also applies to the curing of the test specimens. In other words, if one of the cylinders (out of the three) was improperly sampled, molded, tested, or cured, that cylinder shall be thrown away and the test result will be based on the average of the two remaining cylinders. Likewise, if more than one cylinder (out of the three) was improperly sampled, molded, tested, or cured, the entire test will be considered invalid and acceptance of the concrete will be performed on a statistical basis (the same method as low strength cylinders, see section 601.4.4) or by cores.

Cylinders are made and tested in sets of 3 in order to give a more accurate measure of the compressive strength of the sample.

Because the specimens are tested in sets of 3, it is desirable to mold the specimens simultaneously. This is done by filling each of the molds in the set 1/3 full and rodding each mold before the next layer is added. All molds are alternately filled and rodded until they are struck off. Section 601.4.4 also places limits on the variability of compressive strengths within a set of cylinders. The procedure and allowable ranges are outlined in section 601.4.4.

In summary at this point we have stated that:

1. The compressive strength of concrete is expressed in pounds per square inch (psi).
2. It is required that the cylinder mold has a height that is twice its diameter, and the diameter is 3 times larger than the **nominal maximum size** of coarse aggregate in the concrete (see the definition of nominal maximum size of Page 5-30).
3. Specimens are normally tested to check the adequacy of the laboratory mixture proportions for strength, a basis for acceptance, or to determine when a structure may be put into service (also form removal).
4. The sample must be representative of the concrete used in the structure and must be protected from sunlight and wind during the period between sampling and using. The period between the sampling and the beginning of molding of the test cylinders must not exceed 15 minutes.
5. The compressive strength test consists of a set of three specimens, which should be molded simultaneously.
6. If cylinders are not sampled, molded, or cured in accordance with the specifications, they are not to be tested.

Now that we have discussed the reasons that we need test cylinders and the way we use the compressive strength of these cylinders, we will describe the procedure for molding and curing the specimens.

Equipment - The equipment needed for this test consists of:

1. 3 Molds - 6 in. x 12 in. or 4 in. x 8 in. if allowed in accordance with MP 711.03.23 (Non-absorbent and Non-reactive)
2. Tamping Rod –

   For 6 in. x 12 in. cylinders: Straight steel rod 5/8-inch diameter and approximately 20 inches long, having one end rounded to a hemispherical tip whose diameter is 5/8 inch.

   For 4 in. x 8 in. cylinders: Straight steel rod 3/8-inch diameter and approximately 12 inches long, having one end rounded to a hemispherical tip whose diameter is 3/8 inch.
3. Scoop
4. Suitable Covering Material – Glass, a plastic cap, a piece of durable plastic, or some other non-reactive material that will prevent evaporation of water from the unhardened specimens.
5. Rubber Mallet weighing 1.25 ± 0.5 lb
6. Trowel or Wood Float
7. Vibrator (for low slump concrete) with a frequency of at least 7000 vibrations per minute (117 Hz) while operating in the concrete. Round vibrators shall have a diameter of no more than one-fourth (25%) the diameter of the cylinder mold. The combined length of the vibratory shaft and the vibrating element shall be at least 3 inches greater than the depth of the section being vibrated.

Procedure

The 3 cylinder molds should be placed on a level, rigid, horizontal surface that is free from vibration and located as near as practical to the place where they are to be stored for the first 24 $\pm$ 8 hours (curing box). Now that we have the 3 cylinder molds placed and the sample re-mixed, it is time to start molding the specimens.

1. Place the concrete in the 3 molds using a scoop. Select each scoop of concrete from the sample to ensure that it is representative of the batch. Move the scoop around the top edge of the mold as the concrete is being discharged in order to ensure a symmetrical distribution of the concrete and to minimize segregation of the sample. Depending on their size and method of consolidation, cylinder molds are filled as shown in Tables 5-1 and 5-2 below. Further distribute the concrete by use of a tamping rod prior to consolidation.

Table 5-1 – Molding Requirements by Rodding

Cylinder Size (Diameter)	Number of Layers of Approximately Equal Depth	Number of Roddings per Layer
4 inches	2	25
6 inches	3	25

Table 5-2 – Molding Requirements by Vibration

Cylinder Size (Diameter)	Number of Layers of Approximately Equal Depth	Number of Vibrator Insertions per Layer
4 inches	2	1
6 inches	2	2

2. Consolidation - Concrete with a slump of greater than 1 inch may be consolidated by rodding or vibration. Concrete with a slump of 1 inch or less must be consolidated by vibration.

2.1 Consolidation by Rodding – Place the concrete in the 3 molds, in the number of layers (of approximately equal volume) required in Table 5-1. Rod each layer with the rounded end of the rod. The number of roddings per layer is shown in Table 5-1. Distribute the strokes uniformly over the cross section of the mold and allow the rod to penetrate throughout the depth of the layer and into the layer below by approximately 1 inch. After each layer is rodded, tap the outside of the 3 molds lightly 10 to 15 times with the mallet (or an open hand if using single-use molds that are susceptible to damage when struck by a mallet) to close any holes left by rodding and to release any large air bubbles that may have been trapped.

2.2 Consolidation by Vibration - Place the concrete in the 3 molds, in the number of layers (of approximately equal volume) required in Table 5-2. Place all of the concrete for each layer in the mold before starting vibration of that layer. Insert the vibrator at the number of locations per layer as shown in Table 5-2. Insert the vibrator slowly, do not allow it to rest on the bottom or sides of the mold, then slowly withdraw the vibrator so that no large air pockets are left in the specimen. When more than one insertion per layer is required, distribute the insertions uniformly within each layer. Allow the vibration to penetrate through the layer being vibrated and into the layer below, approximately 1 inch. The duration of vibration required will depend on the workability of the concrete and the effectiveness of the vibrator. Usually, sufficient vibration has been applied as soon as the surface of the concrete has becomes relatively smooth and large air bubbles cease to break through the top surface. After each layer is vibrated, tap the outside of each mold lightly at least 10 times with the mallet to close any holes left by vibrating and to release any large air bubbles that may be trapped. When placing the final layer, avoid overfilling by more than ¼ inch.

3. After all the molds have been consolidated (either by rodding or vibration), the remainder of the procedure is the same. Strike off the surfaces of the concrete in the 3 molds, and float or trowel the surfaces as required. Perform the finishing with the minimum manipulation necessary to produce a flat even surface that is level with the rim of the mold (no depressions or projections more than 1/8 inch are permitted).

4. Immediately after being struck-off, move the 3 cylinders to the storage place where they will remain undisturbed for the initial curing period. If single-use molds are used, support them from the bottom (with a trowel or similar device) if they are moved.

There are two types of curing methods used - 1. Standard Curing and 2. Field Curing. Both curing procedures and the reasons for each procedure are discussed below.

Standard Curing

Standard curing is the curing method used when the specimens are either made and cured for the purpose of acceptance testing for specified strength, or for checking the adequacy of mixture proportions for strength.

Storage

If specimens cannot be molded at the place where they will receive initial curing, immediately after finishing, move the specimens to an initial curing place for storage. The surface on which they will be stored must be level to within ¼ inch per foot.

Initial Curing

Immediately after molding and finishing, the specimens shall be stored for a period of 24 ± 8 hours (in accordance with MP 601.04.20) in a temperature range from 16 to 27˚C (60 to 80˚F), and in an environment preventing moisture loss from the specimens. For concrete mixtures with a specified strength of 40 MPa (6000 psi) or greater, the initial curing temperature shall be between 20 and 26˚C (68 and 78˚F). Various procedures are capable of being used during the initial curing period to maintain the specified moisture and temperature conditions. An appropriate procedure or combination of procedures shall be used (see the note below). Shield all specimens from direct sunlight and, if used, radiant heating devices. The storage temperature shall be controlled by the use of heating and cooling devices, as necessary. Record the temperature using a maximum-minimum thermometer. If cardboard molds are used, protect the outside surface of the molds from contact with wet burlap or other sources of water.

Note: A satisfactory moisture environment can be created during the initial curing of the specimens by one or more of the following methods: (1) immediately immerse molded specimens with plastic lids in water saturated with calcium hydroxide, (2) store in properly constructed wood boxes or structures, (3) place in damp sand pits, (4) cover with removable plastic lids, (5) place inside plastic bags, (6) cover with plastic sheets or nonabsorbent plates if provisions are made to avoid drying and damp burlap is used inside the enclosure, but the burlap is prevented from contacting the concrete surfaces. A satisfactory temperature environment can be controlled during the initial curing of the specimens by one or more of the following methods: (1) use of ventilation, (2) use of ice, (3) use of thermostatically controlled heating or cooling devices, or (4) use of heating methods such as stoves or light bulbs. Other suitable methods may be used if the requirements limiting specimen storage temperature and moisture loss are met.

It is the Inspector's responsibility to ensure that the cylinders are kept in a temperature range from between 60 °F to 80 °F during this initial curing period. If the cylinders are not kept in this temperature range during the initial curing period, these cylinders become invalid and cannot be used for acceptance, as they are now useless.

Final Curing

Upon completion of initial curing and within 30 minutes after removing the molds, store specimens in a moist condition with free water maintained on their surfaces at all times at a temperature of 73.5 ± 3.5 °F (except when capping with sulfur mortar capping compounds and immediately before testing). The specimens shall be maintained at this temperature until the time of testing. For a period not to exceed three hours immediately prior to test, standard curing temperature is not required provided that free moisture is maintained on the cylinders and ambient temperature is between 20 to 30˚C (68 to 80˚F).

Field Curing

Field curing is the curing method used for specimens that are to be used for the following purposes: (1) determination of whether a structure is capable of being put into service, (2) comparison with test results of standard cured specimens or with test results from various in-place test methods, (3) adequacy of curing and protection of concrete in the structure, or (4) form removal time requirements.

Store cylinders in or on the structure as close as possible to the location where the concrete represented was placed. Protect the cylinders from the elements in as close as possible to the same way as the represented concrete is protected (formed concrete, etc.). The cylinders are to be kept at the same temperature and moisture condition as the represented concrete. Test the cylinders in the moisture condition that results from the specified curing conditions. To meet these conditions, cylinders made for determining when a structure may be put into service shall be removed from the molds at the same time the formwork is removed from the represented concrete.

Transporting Cylinders To The Laboratory

Prior to transporting, cure and protect specimens as previously required. Specimens that are cured by standard curing shall be transported within **24 ± 8 hours after molding (in accordance with MP 601.04.20)**. Specimens that are cured by field curing shall not be transported to the lab until just prior to testing. During transporting, protect the specimens with suitable cushioning material to prevent damage from jarring. During cold weather, protect the specimens from freezing with suitable insulation material. Prevent moisture loss during transportation by wrapping the specimens in plastic, wet burlap, by surrounding them with wet sand or tight fitting plastic caps on plastic molds. Transportation time shall not exceed 4 hours.

To summarize the curing procedure for standard curing, the following is stated:

1. During initial curing (24 ± 8 hours) the specimens shall be stored at a temperature of 60 to 80 °F and water shall be prevented from evaporating from the specimens.
2. The specimens shall either be stored in a wooden box (or similar curing structure), in temporary buildings at the construction site, in damp sand pits, or immersed in water.
3. Specimens formed in cardboard molds shall not be in contact with water in any condition that would allow the outside of the mold to absorb water.
4. After initial curing is finished (24 ± 8 hours), transport the cylinders to the lab, and within 30 minutes after removing the molds, store specimens in a moist condition at a temperature of 73.5 ± 3.5 °F until testing.

To summarize the curing procedure for field curing:

These cylinders shall be placed on or near the structure they represent and cured in the same manner as the structure they represent. The specimens are to be tested in the moisture condition resulting from the curing treatment.

Testing

As stated earlier, the compressive strength of concrete specimens is determined in accordance with AASHTO T 22, Compressive Strength of Molded Concrete Cylinders. The testing machine shall conform to the requirements stated in the above standard method of test.

The compression test of moist cured specimens should be made as soon as possible after their removal from moist storage. These specimens should be kept moist during the time between removal from the curing room and testing by applying a wet blanket or burlap.

All test specimens for a given test age shall be broken within the permissible time tolerances as follows:

Table 2 – Permissible Time Tolerances

Test Age	Permissible Tolerance
12 h	±0.25 h or 2.1%
24 h	±0.5 h or 2.1%
3 days	2 h or 2.8%
7 days	6 h or 3.6%
28 days	20 h or 3.0%
56 days	40 h or 3.0%
90 days	2 days or 2.2%

Ends of the specimens may be capped with a sulfur mortar prior to testing. The procedure for capping test specimens is described in AASHTO T 231, Capping Cylindrical Concrete Specimens. The use of neoprene caps is considered a suitable alternative to capping with sulfur mortar. The use of neoprene caps is covered in ASTM C 1231 (AASHTO T 22 references ASTM C 1231).

A cylinder should not be tested if a diameter of that cylinder (taken in one direction) differs from any other diameter (taken in another direction) of that same cylinder by more than 2 percent. The diameter of the test specimen is to be determined to the nearest 0.01 inch by averaging two diameters measured at right angles to each other about mid-height. This average is used to calculate the cross-sectional area that is used in the determination of compressive strength.

Also, cylinders are not to be tested if either end of the cylinder departs perpendicularly to the axis by more than 0.5 degrees (approximately 0.12 inches in 12 inches). If this value is exceeded or if the ends are not plane within 0.002 inches, the ends shall be sawed or ground to meet that tolerance or capped in accordance with AASHTO T 231 or, when permitted, neoprene caps may be used in accordance with ASTM C 1231.

The test specimens should be placed in the compression machine so that the axis of the specimen is aligned with the center of the spherically seated bearing block. As the spherically seated block is brought to bear on the specimen, its movable portion should be rotated by hand so uniform seating is obtained.

The load shall be applied at a rate of movement corresponding to a stress rate on the specimen of 35 ± 7 psi per second. The designated rate of movement shall be maintained at least during the latter half of the anticipated loading phase. During the first half of the anticipated load, a higher loading rate is permitted, but the rate should not be adjusted while the specimen is yielding rapidly before failure.

After the specimen fails, record the maximum load carried by the specimen during the test. Note the type of failure exhibited by the cylinder (these different types of failures are shown in Figure 2 AASHTO T 22, and they are also shown on WVDOH form T600).

Calculation of Load

The compressive strength of the specimen is calculated by dividing the maximum load carried by the specimen by the average cross-sectional area. This calculation and the correct rounding procedure are covered in section 2.2.6.1 of MP 601.03.50 and are as follows:

When calculating the compressive strength of concrete cylinders in accordance with AASHTO T22, the following procedure shall be used:

$$CS = \frac{ML}{0.25 \times \pi \times D^2}$$

Where:

CS = Compressive strength of the specimen

ML = Maximum load carried by the specimen during the test

Π = Mathematical constant PI

D = Diameter of the cylinder being tested (in accordance with AASHTO T 22)

Note: The calculation for CS shall be performed in one continuous step (without any rounding), either by the testing machine, or by calculating device, and only the final value (CS) is permitted to be rounded (to the accuracy specified in AASHTO T 22). The value for Π shall be the manufacturer's pre-programmed value in a calculating device or the testing machine.

Note: When recording the area of the section (cross-sectional area of the cylinder) on the T600 form, record the area rounded to two decimal places.

Example:

Determine the compressive strength of a concrete cylinder whose average cross-sectional diameter is 6.00 inches and when broken sustained a maximum load of 10,6140 pounds.

Therefore: D = 6.00 inches and ML = 10,6140 lbs.

$$CS = \frac{ML}{0.25 \times \pi \times D^2} = \frac{10{,}6140\,lbs.}{0.25 \times \pi \times 6.00^2} = 3753.93\,lb/in^2$$

This, in accordance with AASHTO T 22, shall be reported to the nearest 10 psi. Therefore, the final answer would be 3750 psi.

The three compressive strengths of the specimens in a set are then averaged and this average is used to represent the compressive strength of the concrete sample and the concrete structure.

Example:

You test three cylinders representing class B concrete (3000 psi minimum compressive strength as per WVDOH standard specifications, section 601) and determine that their compressive strengths are as follows:

Cylinder 1 = 3130 psi Cylinder 2 = 3020 psi Cylinder 3 = 2810 psi

Would this set of cylinders meet the requirements for class B concrete?

We must find the average strength of this set of cylinders in order to determine if this set of cylinders will meet the requirements for class B concrete.

$$\text{Average} = \frac{3130\text{ psi} + 3020\text{ psi} + 2810\text{ psi}}{3} = 2987\text{ psi}$$

Since 2987 psi is less than 3000 psi, these cylinders would not meet the requirements for class B concrete.

<u>Allowable Variability Within a Set of Cylinders</u>

Because of such factors as small variability within aggregates in a set of cylinders and the uniformity of mixing concrete when batched, there will naturally be some variation between the compressive strength results of each cylinder within a set. There may also be variability within a set of cylinders due to improper sampling practices and improper cylinder fabrication technique. The WVDOH specifications allow a range of 9.5% within a set of three cylinders and a range of 8.0% within a set of two cylinders. Any variability beyond these ranges is most likely due to improper sampling and/or testing procedures. Section 601.4.4 of the WVDOH specifications states:

The maximum acceptable range of compressive strengths within a set of three cylinders is 9.5%. This range is found by multiplying 9.5% times the average compressive strength of the three cylinders. If this acceptable range is exceeded, the cylinder that varies the most from the average shall be discarded, and the remaining two cylinders shall be evaluated as outlined in the following paragraph.

The maximum acceptable range of compressive strengths within a set of two cylinders is 8.0%. This range is found by multiplying 8.0% times the average compressive strength of the two cylinders. If this acceptable range is exceeded, the entire test shall be discarded. Under no circumstances shall a compressive strength test consist of less than the average of two specimens.

This specification basically states that any cylinders beyond the allowable range will be discarded due to the likelihood that the variability is due to improper sampling and/or testing procedures. Examples of this calculation are shown on the following pages.

Example 1: You have a set of three cylinders with the following compressive strengths: 3970 psi, 4120 psi, and 4380 psi.

$$\frac{3970 + 4210 + 4380}{3} = 4186.67 \text{ psi (average compressive strength)}$$

0.095 x 4186.67 psi = 397.73 psi (allowable range)

4186.67 – 397.73 = 3788.94 psi (lower limit of allowable range)

4186.67 + 397.73 = 4584.40 psi (upper limit of allowable range)

All of the cylinders were within the acceptable range, so we use all three cylinders

$3788.94 < 3970, 4210, 4380 < 4584.40$

Example 2: You have a set of three cylinders with the following compressive strengths: 3610 psi, 4250 psi, and 4630 psi.

$\frac{3610 + 4250 + 4630}{3}$ = 4163.33 psi (average compressive strength)

0.095 x 4163.33 psi = 395.52 psi (allowable range)

4163.33 – 395.52 = 3767.81 psi (lower limit of allowable range)

4163.33 + 395.52 = 4558.85 psi (upper limit of allowable range)

The cylinders with compressive strengths of 3610 and 4630 were beyond the acceptable range, so we must discard one.

4163.33 – 3610 = 553.33 psi (amount that this cylinder varies from the average)

4630 - 4163.33 = 466.67 psi (amount that this cylinder varies from the average)

Therefore, since it’s further from the average, we discard the cylinder with a strength of 3610. Now we must evaluate the two remaining cylinders:

$\frac{4250 + 4630}{2}$ = 4440 psi (average compressive strength of the two remaining cylinders)

0.08 x 4440 psi = 355.20 psi (allowable range between the two remaining cylinders)

4440 – 355.20 = 4084.80 psi (lower limit of allowable range)

4440 + 355.20 = 4795.20 psi (upper limit of allowable range)

Both of the two remaining cylinders were within the acceptable range, so we use the average of their two strengths as the final result.

$4084.89 < 4250, 4630 < 4795.20$

Example 3: You have a set of three cylinders with the following compressive strengths: 3290 psi, 3900 psi, and 4960 psi.

$$\frac{3290 + 3900 + 4960}{3} = 4050 \text{ psi (average compressive strength)}$$

0.095 x 4050 psi = 384.75 psi (allowable range)

4050 – 384.75 = 3665.25 psi (lower limit of allowable range)

4050 + 384.75 = 4434.75 psi (upper limit of allowable range)

The cylinders with compressive strengths of 3290 and 4960 were beyond the acceptable range, so we must discard one.

4050 – 3290 = 760 psi from the average (amount that this cylinder varies from the average)

4960 - 4050 = 910 psi from the average (amount that this cylinder varies from the average)

Therefore, since it’s further from the average, we discard the cylinder with a strength of 4960. Now we must evaluate the two remaining cylinders.

$$\frac{3290 + 3900}{2} = 3595 \text{ psi (average compressive strength of the two remaining cylinders)}$$

0.08 x 3595 psi = 287.60 psi (allowable range between the two remaining cylinders)

3595 – 287.60 = 3307.40 psi (lower limit of allowable range)

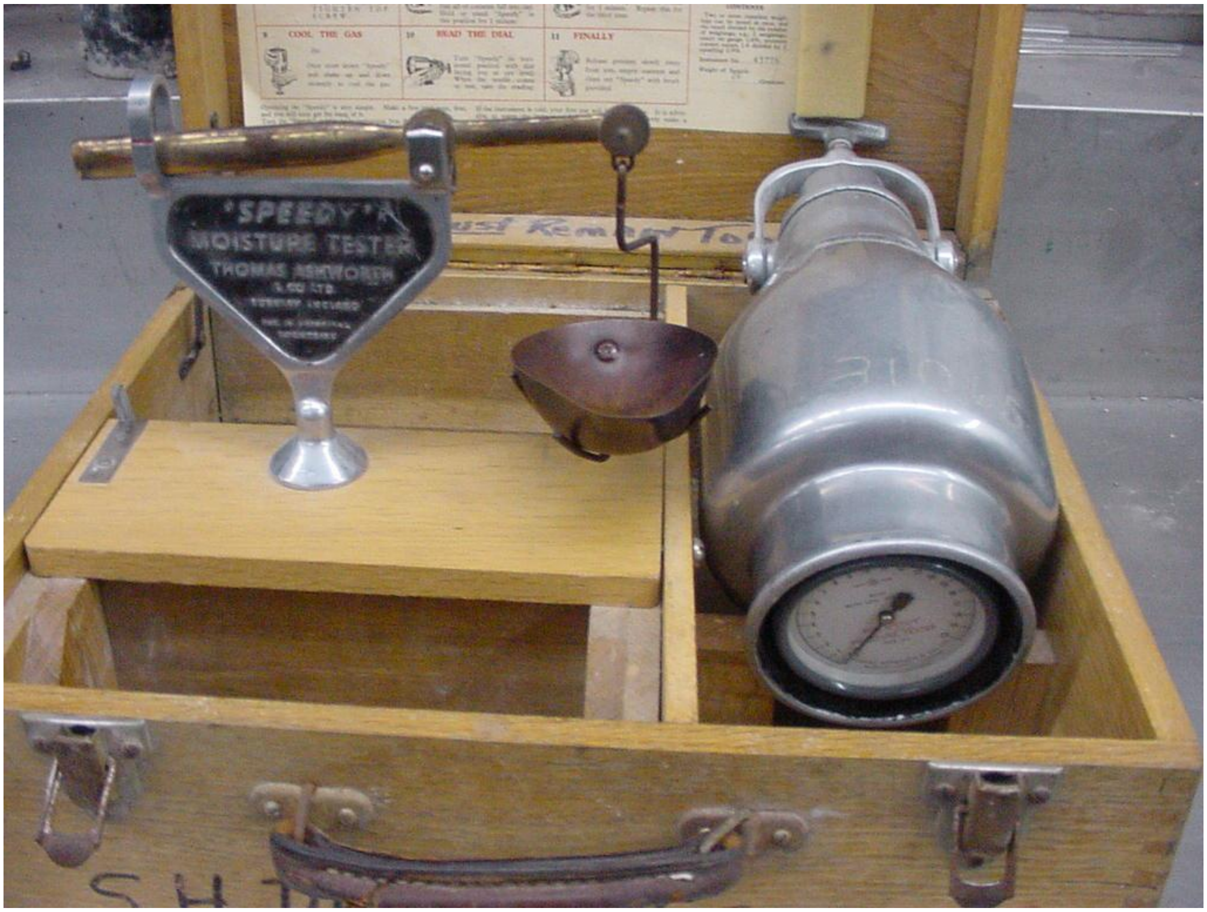
3595 + 287.60 = 3882.60 psi (upper limit of allowable range)

The two remaining cylinders were not within the acceptable range of 8%, so we discard the entire test.

3307.40 > 3290 and also 3900 > 3882.60

SECTION 5.6

SPEEDY MOISTURE TEST



The speedy moisture test is a fast way to get the moisture content of the fine aggregate to be used when batching concrete. It is a useful test at the batch plant, but also, it can be useful in the field such as when mobile mixers are used to batch concrete. It can be very helpful to know how to perform this test, but it is no longer one of the tests on which a PCC Inspector candidate will be tested. The procedure for performing a speedy moisture test is as follows:

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION
MATERIALS PROCEDURE

DETERMINING FREE MOISTURE IN FINE AGGREGATE USING A "SPEEDY MOISTURE TESTER"

1.0 PURPOSE

1.1 To establish a standard method of test for determining free moisture (moisture above saturated surface dry) in fine aggregate using a "Speedy Moisture Tester".

2.0 SCOPE

2.1 This method of test is applicable to free moisture determination when using either the 20-gram or 26-gram "Speedy Moisture Tester".

3.0 GENERAL

3.1 Concrete design computations are based on aggregates, which are in the SSD condition. Therefore, in this procedure the expression of free moisture is based on the SSD weight of the material.

3.2 The dial reading on the "Speedy Moisture Tester" is the percent total moisture based on the wet weight of the sample. The average absorption for limestone and silica sand is approximately 1.5 percent based on the dry weight of the material. Conversion tables calculated from this average are provided on Attachment I to yield the percent free moisture in the sample from the dial reading of the "Tester".

3.3 If it is known that the absorption should not be based on the 1.5 percent average (when the absorption is less than 1 or greater than 2) then the method for calculating the free moisture from the dial reading is given in Section 6.0.

4.0 EQUIPMENT

4.1 All equipment is contained in a "Speedy Moisture Tester" kit as obtained from a laboratory equipment supplier and consists of the following:

a) 20-gram or 26-gram tester (body and cap)
b) Simple beam type scale
c) Reagent measurer
d) Reagent - calcium carbide
e) Cleaning cloth and brush

5.0 PROCEDURE

a) Place the scale in operating position and clean the pan.
b) Ensure the inside of the body of the tester is free from all foreign matter.
c) Add three measures of the reagent to the body of the tester.
d) Accurately weigh the sample (20 g or 26 g) on the scale. The accuracy of the scale should be established periodically.
e) Place the weighed sample in the cap of the tester.
f) With the pressure vessel in an approximately horizontal position, insert the cap in the pressure vessel and seal the unit by tightening the clamp, taking care that no reagent comes in contact with the aggregate until a complete seal is achieved.
g) Place the tester in a vertical position (cap end up) so that the aggregate will fall into the pressure vessel.
h) Shake the tester vigorously from end to end. At the first movement of the dial needle, turn the dial end up.
i) When the needle stops moving, read the dial while holding the instrument in a horizontal position at eye level. Read to the nearest 0.1 percent.
j) The percent free moisture is determined by entering the conversion chart (Attachment I) with the dial reading and obtaining the corresponding value of free moisture in the opposite column, or by substituting the dial reading into the equation shown in Section 6.0 – whichever the case may be.

6.0 SAMPLE CALCULATION

6.1 The following method for determining free moisture should be used when the absorption capacity of the aggregate is known to be outside the range of 1 percent to 2 percent (average 1.5 percent) of the aggregate dry weight (see Section 3.3).

Symbols	**Given**
W_D = Dry Weight	AB = 3.0%
W_{SSD} = Saturated Surface Dry Weight	DR = 10.0
Ww = Wet Weight (Sample Weight)	*Ww = 20.0 or 26.0
DR = Dial Reading	*Dependent upon size tester used
AB = Absorption	
FM = Free Moisture	

1. Determine the sample dry weight:

$$W_D = Ww - \frac{(Ww) \times DR}{100}$$

Substituting:

$$W_D = 26.0 - \frac{(26.0) \times 10.0}{100}$$

$$W_D = 26.0 - 2.6$$
$$W_D = 23.4 \text{ g (dry weight)}$$

2. Determine from the dry weight the SSD weight:

$$W_{SSD} = W_D + \frac{W_D \times (AB)}{100}$$

Substituting:

$$W_{SSD} = 23.4 + \frac{23.4 \times (3.0)}{100}$$

$$W_{SSD} = 23.4 + 0.702$$
$$W_{SSD} = 24.1 \text{ g (SSD weight)}$$

3. Determine from the SSD weight the percent free moisture:

$$\%FM = \frac{(Ww - W_{SSD}) \times 100}{W_{SSD}}$$

Substituting:

$$\%FM = \frac{(26.0 - 24.1) \times 100}{24.1}$$

$$\%FM = \frac{190}{24.1}$$

$\%FM = 7.9$ (percent free moisture)

SPEEDY MOISTURE TESTER CONVERSION CHART

SPEEDY DIAL READING SURFACE WET BASIS	FREE MOISTURE SATURATED-SURFACE DRY BASIS	SPEEDY DIAL READING WET BASIS	FREE MOISTURE SATURATED-DRY BASIS
1.0%	----	17.0%	18.7%
1.5%	----	17.5%	19.4%
2.0%	0.5%	18.0%	20.1%
2.5%	1.0%	18.5%	20.8%
3.0%	1.6%	19.0%	21.6%
3.5%	2.1%	19.5%	22.4%
4.0%	2.6%	20.0%	23.1%
4.5%	3.2%	20.5%	23.9%
5.0%	3.7%	21.0%	24.7%
5.5%	4.2%	21.5%	25.5%
6.0%	4.8%	22.0%	26.3%
6.5%	5.4%	22.5%	27.1%
7.0%	5.9%	23.0%	27.9%
7.5%	6.5%	23.5%	28.8%
8.0%	7.1%	24.0%	29.6%
8.5%	7.7%	24.5%	30.4%
9.0%	8.3%	25.0%	31.3%
9.5%	8.9%	25.5%	32.2%
10.0%	9.5%	26.0%	33.1%
10.5%	10.1%	26.5%	34.0%
11.0%	10.7%	27.0%	34.9%
11.5%	11.4%	27.5%	35.8%
12.0%	12.0%	28.0%	36.8%
12.5%	12.6%	28.5%	37.8%
13.0%	13.2%	29.0%	38.7%
13.5%	13.9%	29.5%	39.7%
14.0%	14.6%	30.0%	40.7%
14.5%	15.2%	30.5%	41.8%
15.0%	15.9%	31.0%	42.8%
15.5%	16.6%	31.5%	43.8%
16.0%	17.3%	32.0%	44.9%
16.5%	18.0%	32.5%	46.0%
----	----	33.0%	47.0%

CHAPTER 6

RELATIONSHIP OF CONCRETE PROPERTIES

CHAPTER 6

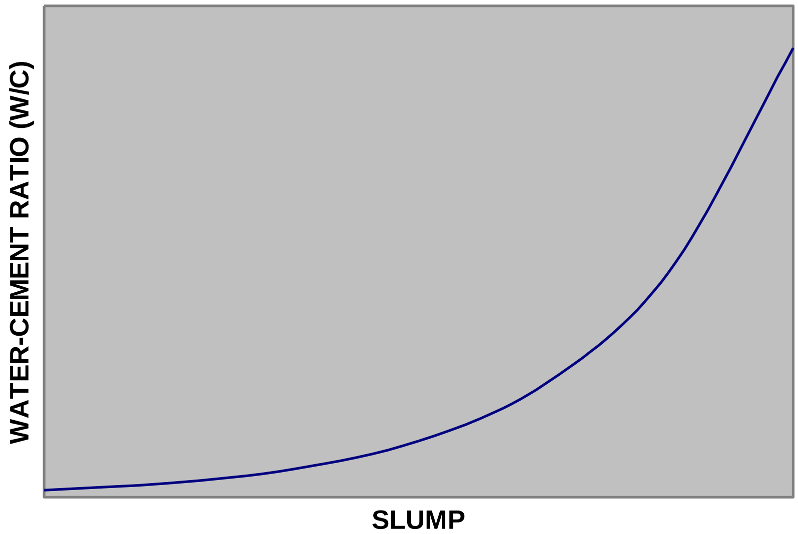
RELATIONSHIP OF CONCRETE PROPERTIES

Now that we have studied what concrete is, how it is made, the types of equipment used, and how to conduct the tests to determine the properties of concrete, we need to tie all of this together.

Now that we have some understanding of these basics, we can examine how different properties of concrete affect each other. For example, what does the result of the slump test tell us? What factors affect the slump of Portland cement concrete?

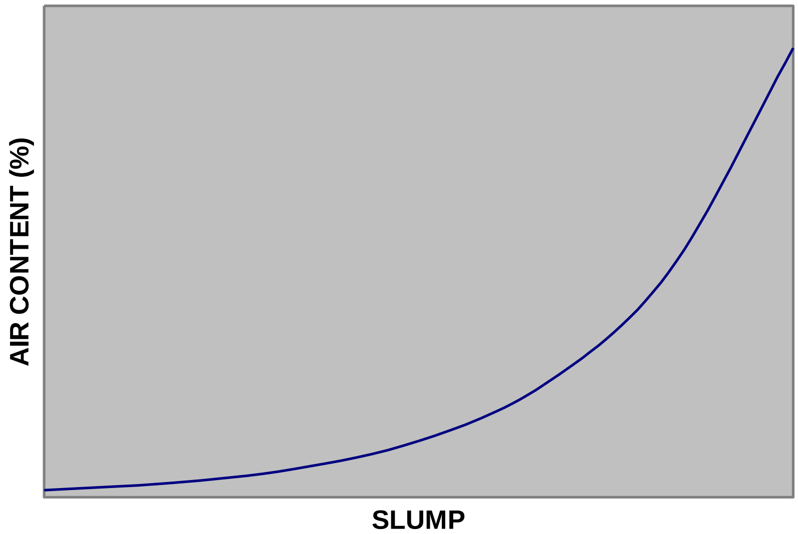
The following charts will be used to define the relationships between slump and the other concrete properties that affect the slump. For the purpose of this class, we will be assuming that the charts are based on a concrete mix that contains no water-reducing admixtures, and therefore, an increased slump is a result of increased water content.

SLUMP VS WATER-CEMENT RATIO (W/C)



As you can see in the chart, as the water cement ratio increased the slump also increases. Once the slump gets to a point where it is not measurable, an increase in the W/C Ratio has no measurable effect. A general rule of thumb is: For each three percent increase in water, you can expect a one-inch increase in slump. The reverse also holds true; if the water decreases by three percent, the slump will decrease approximately one-inch.

SLUMP VS AIR CONTENT



As the air content of the concrete increases there will be a corresponding increase in slump.

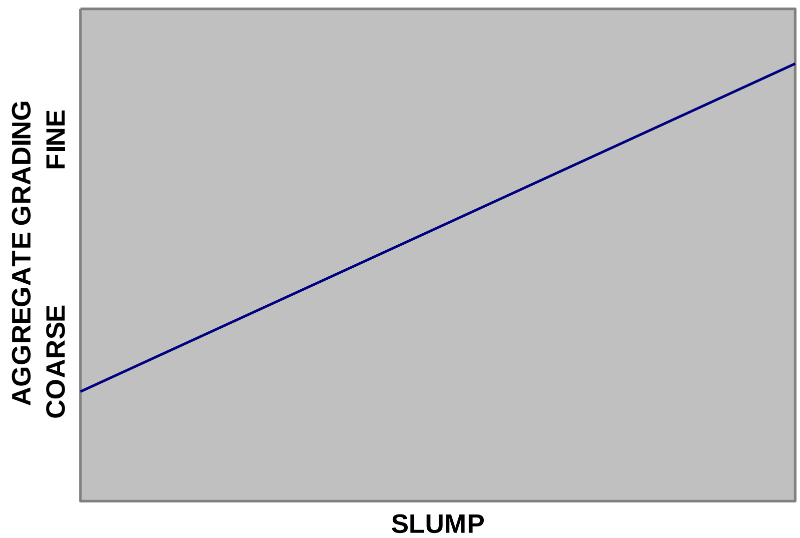
A general rule of thumb is: you will get a one-inch increase in slump for each 1/2 to 1 percent increase in air content.

Thus far we have two properties that can cause variation in the slump test result.

A question that readily pops to mind is: If the slump test result is higher than desired, what is indicated? Is there too much water? Is there too much air?

Can you really tell without further investigation?

SLUMP VS AGGREGATE GRADING

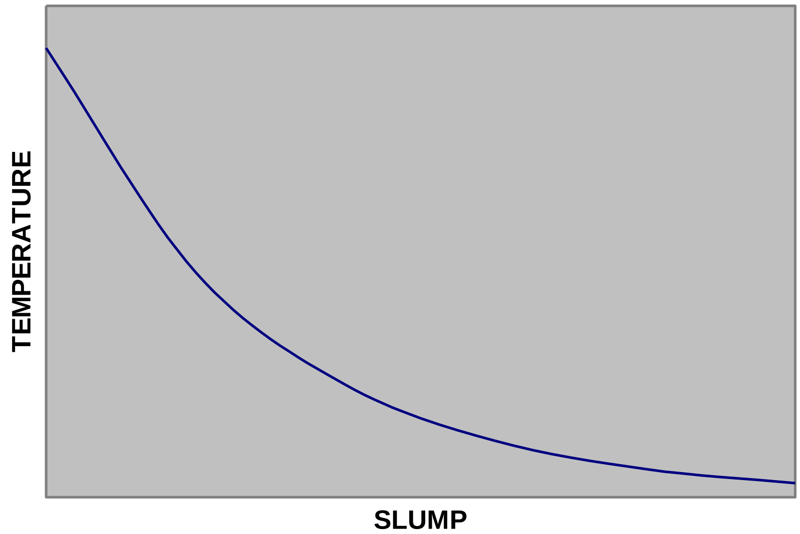


Concrete with a given amount of water will become more plastic (higher slump) as the grading becomes finer. Of course there is a limit to the effect extra fines will have on the slump.

This is because when the grading is coarser, more water is required to fill the voids between the aggregates. As the grading becomes finer, it takes less water to fill these voids, and the excess water will result in a higher slump.

So now we have three properties that directly affect the slump of concrete.

SLUMP VS TEMPERATURE



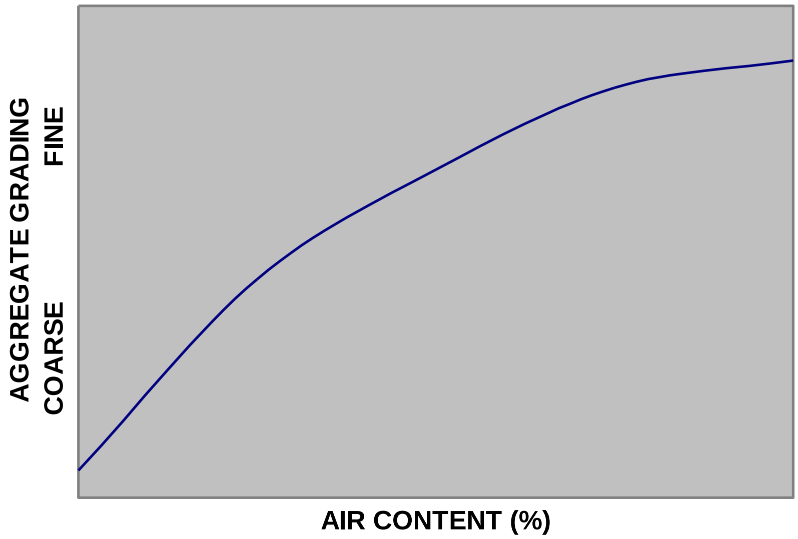
As the temperature of the concrete increases, the slump will decrease. This might also be stated: as the temperature of the concrete increases, the amount of water needed to maintain a constant slump would increase.

Now we have four factors affecting the slump of concrete.

A better judgment can be made when we have more than one test result on which to base our judgment.

Some of these same factors affect the air content of Portland cement concrete. Entrained air is generally achieved through the use of an admixture, however, if the quantity of admixture is held constant, other factors can cause a variation in air content.

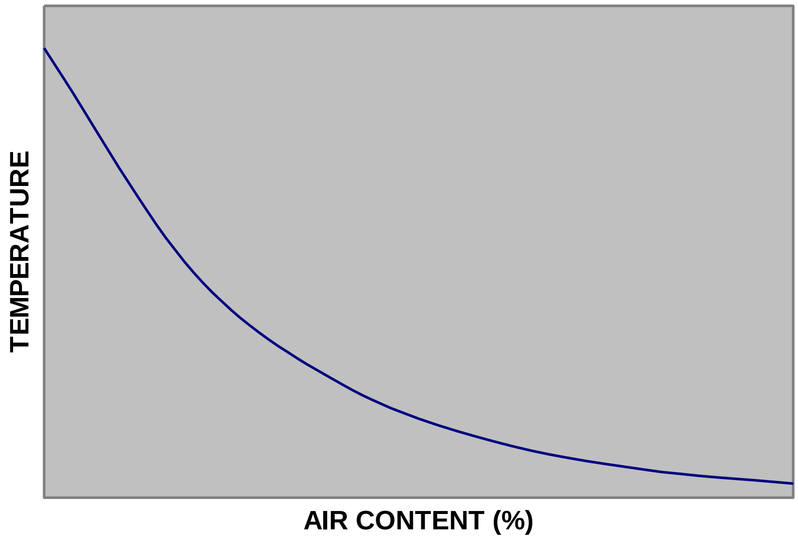
AIR CONTENT VS AGGREGATE GRADING



Since the air is entrained in the mortar fraction of the concrete, the coarser aggregate particles have little effect on the air content.

There are, however, certain fine aggregate fractions that greatly affect the air entrainment. The air content increases as the aggregate size decreases.

AIR CONTENT VS TEMPERATURE

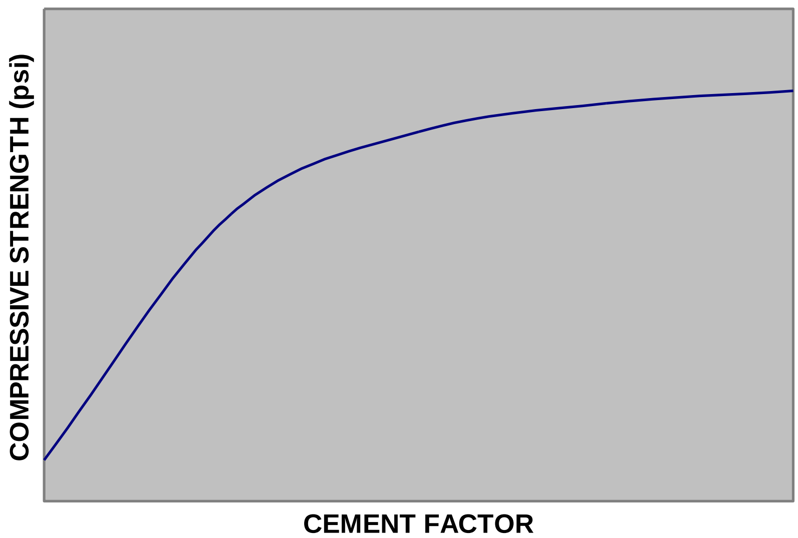


As the temperature of the plastic concrete goes up, the entrained air content will decrease.

Many of the factors that affect the air content of concrete also affect the slump. The air content of concrete affects the slump. These two properties, therefore, are very closely tied together. To realistically evaluate one, the other must be measured.

The final possible measurement made on Portland cement concrete is its strength as determined from strength specimens. There are many factors that affect the strength of concrete.

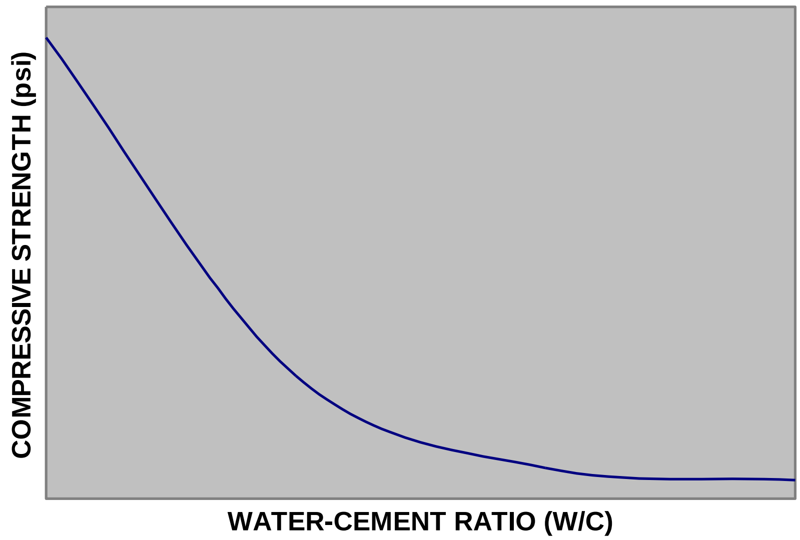
COMPRESSIVE STRENGTH VS CEMENT FACTOR



The cement factor (how many pounds of cement per unit volume of concrete) has the greatest affect on the strength of Portland cement concrete.

As the cement factor (cement content) increases, the compressive strength also increases.

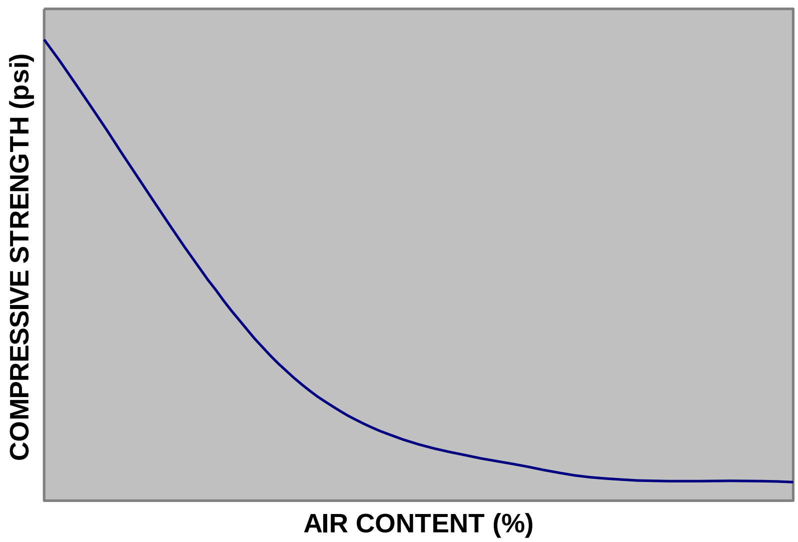
COMPRESSIVE STRENGTH VS WATER CEMENT RATIO



As the water cement ratio increases, the strength decreases. This is the first in a chain of properties that affect each other, and ultimately affect the strength.

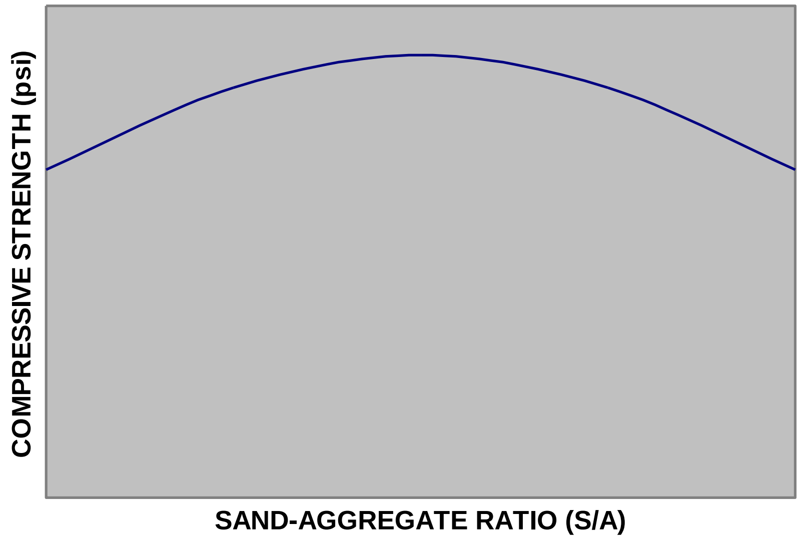
Since the slump is a rough measure of the water cement ratio, a high slump would generally mean lower strengths. An important exception to this is when admixtures such as high-range water reducers (superplasticizers) are used to achieve a high slump. These superplasticizers can be added to a concrete mix that has a low water-cement ratio, and the slump will increase with no loss of strength (no water was added, and the water-cement ratio was not raised). There is another problem encountered, though, when the slump of concrete is high. This is the problem of segregation.

COMPRESSIVE STRENGTH VS AIR CONTENT



As the air content of concrete increases, the strength of the concrete decreases. Some entrained air is needed in concrete for the purpose of freeze-thaw resistance and possibly other factors. A balance must be achieved between the desired strength and the desired entrained air content.

COMPRESSIVE STRENGTH VS SAND-AGGREGATE RATIO



The sand-aggregate ratio can be either too high or too low for optimum strength.

The sand-aggregate ratio should be such that there are sufficient fines to allow for a dense mix but not an excess of fines, which would tend to spread the available paste thin.

Conclusion

The conclusion to this story of the man made rock will be brief. If a concrete mix is properly designed, properly controlled during production, and properly tested to determine the variables, the end result can be predicted.

We can offer the public, a product that we have proven to be of the highest quality or we can offer them a questionable product. A product that is questionable may result from poor inspection practices. Which will it be?

NOTES

APPENDIX A

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

INFORMATIONAL MEMORANDUM

QUALITY ASSURANCE PROCEDURES

1.0 PLANT AND EQUIPMENT INSPECTION STICKERS

1.1 Physical plants and equipment which prepare materials for or deliver materials to State project shall be regularly inspected and approved by an authorized representative of the Division when such inspections are necessary to insure conformance with Division specifications and directives.

1.2 The inspections and approval shall be witnessed, where applicable, by an inspection sticker supplies by the Materials Control, Soils and Testing Division. The inspection sticker will indicate the following:

1. Name of inspector
2. Date of inspection and
3. Date of expiration of approval

1.3 Inspections may be made at any time at the option of the Division and the status of the inspected facility shall be determined by the latest inspection. The date of expiration of approval, as noted on latest inspection sticker, shall be the last day on which the facility is considered to be approved by Division, and such facility must have an approved status at time of preparing materials for or delivering materials to State projects.

1.4 The sole purpose of the inspection sticker is to inform all concerned that a plant, or portion thereof, or a singular piece of equipment has been inspected and found to meet, substantially, all requirements of the specifications and is, therefore, approved to supply materials to State projects. Said inspection sticker shall therefore be affixed to the equipment or displayed in other manners so that the purpose as above stated will be fulfilled.

1.5 Each District will be supplied with inspection stickers numbered consecutively. The first digit of the sticker numbers issued to a District will correspond to the number of that District. The stickers shall be applied, insofar as practicable, in numerical order, and records shall be maintained by each District which will indicate the following:

1. Plant or portion thereof, or singular piece of equipment inspected.
2. Date of inspection.
3. Expiration date of inspection sticker.
4. Number of inspection sticker.

1.6 A plant or portion thereof, or a singular piece of equipment, shall be approved for a period not to exceed six (6) months. The period of approval shall be determined, in general, by the age, physical condition, or durability of the plant or equipment, and the inspection interval shall be such that the Division will have reasonable assurance that the plant or equipment is maintained in an acceptable manner.

1.7 Additional information regarding inspections and a sample of an inspection sticker is contained on FLOW DIAGRAM NO. 1, copy attached.

2.0 QUALITY ASSURANCE IN PORTLAND CEMENT CONCRETE

2.1 PURPOSE

The purpose of this procedure is to establish guidelines which will aid Division personnel in implementing in a prescribed and uniform manner the Division's Quality Assurance Program for portland cement concrete, said program being directed primarily to maintaining a predetermined and acceptable level of assurance that portland cement concretes do conform to their governing specification.

2.2 DEFINITION OF TERMS

2.2.1 QUALITY ASSURANCE

Quality Assurance is an expression of confidence which the Division has in its program of acceptance testing and inspection which determines conformance of materials and construction to governing specification. A Quality Assurance Program is a planned program of acceptance testing and inspection which is conducted by the Division for the express purpose of maintaining a predetermined and acceptable level of assurance that construction materials do conform to governing specifications. Part of any Quality Assurance Program, of course, is an awareness and knowledge of the producer's Quality Control Program and the level of Quality Control which he maintains.

2.2.2 QUALITY CONTROL

Quality Control is a planned program of testing, inspection and related activities conducted by a concrete producer for the purpose of measuring the various properties of concrete and its component materials which are governed by the specification and controlling these properties within the limits of the specification. Quality Control of portland cement concrete is discussed in detail in CD-318.

2.3 GENERAL DISCUSSION

During the past several years, the Division and the Contractor-Supplier industry have jointly participated in a program whose primary objective is to improve the quality of concrete in highway construction. When this program is fully implemented and effective, then the Division will run a smaller risk of having non-conforming materials incorporated into the work, and the Contractor-Supplier industry will run a smaller risk of having suitable materials rejected.

The following major developments are outgrowths of the program just mentioned:

2.3.1 Portland cement concrete technicians have now been certified and are available in the Contractor-Supplier industry to implement a program of Quality Control (See definition of PORTLAND CONCRETE TECHNICIAN in Subsection 3.2 of CD-318).

2.3.2 The requirement for a Contractor (or his authorized representative, a subcontractor or a commercial supplier) to do Quality Control of portland cement concrete and to have in his service a Certified Portland Cement Concrete Technician is specified in Subarticles 501.3.2.2 and 601.3.2.2 of the Standard Specifications (1968) entitled QUALITY CONTROL TESTING (See CD-318 for interpretation).

2.3.3 The requirement for a Contractor (or his authorized representative, a subcontractor or a commercial supplier) to have a field laboratory which is equipped and maintained in specified manner so as to aid in the conduct of a Quality Control Program is specified in Subarticles 501.3.3.1 and 601.3.3.1 of the Standard Specification (1968).

2.3.4 Concrete batch plants and hauling equipment are regularly inspected by the Division and approval of same as conforming to requirements of governing specification is attested to by an inspection sticker (See Section 1 of this memorandum for details).

2.3.5 The requirement to do concrete design, using the particular sources of materials which are to be used in the work, is specified in articles 501.3.1 and 601.3.1 of the Standard Specifications (1968). This requirement will allow commercial concrete suppliers to have laboratory design work done just once a year for the various classes of concrete to be supplied, but this procedure guards against the possibility of source materials changing appreciable from one construction season to the next and affecting the quality of subsequent concrete work.

The foregoing is a significant measure of the Contractor-Supplier (producer) potential to do Quality Control of portland cement concrete. It is expected that this potential will not be utilized with the same effectiveness by all producers.

Although all producers will probably maintain an acceptable level of Quality Control, it is reasonable to assume that a number of producers will maintain a level of Quality Control well above the minimum accepted level.

It is generally agreed that an acceptable level of Quality Assurance may be maintained with less acceptance testing ad inspection when the level of Quality Control is increased. This knowledge was not acted on in the past because the elements which are essential to Quality Control were not generally available then. Additionally, a minimum acceptable level of Quality Control could not have been practically established in the past because the producer industry, generally, was not equipped to maintain a positive and sustained level of Quality Control.

The capability to perform a positive and sustained level of Quality Control in practically all producer plants today is now well established (See CD-318 for interpretation). Also, the Division has the means for measuring the level of Quality Control maintained by each producing plant. Accordingly, it would be desirable to pursue a Quality Assurance Program which takes into account the level of Quality Control in a producers plant so that an acceptable level of Quality Assurance could be maintained with a minimum cost (man-hours and dollars) to the Department. As previously stated the purpose of this procedure is to establish guidelines which will aid Department personnel in implementing in a prescribed and uniform manner such a Quality Assurance Program.

2.4 DIRECTIVE

Concrete plants will be inspected in accordance with Section 1 of this memorandum and the condition of conformance will be determined. Those plants which are found to conform to the specifications will be identified as Class A plants and those which do not conform will be identified as Class B plants. The level of Quality Control at each concrete plant will also be evaluated.

Those plants which have a high level of Quality Control will be considered to have a Level 1 Quality Control, and those plants which have a lower level of Quality Control will be considered to have a Level 2. All concrete plants will then be rated with one of the following classification numbers Al, A2 or B.

2.4.1 LEVEL 1 QUALITY CONTROL

All plants producing concrete which reasonably conforms to the specification requirements, and which satisfies the following additional requirements will be considered to have LEVEL 1 Quality Control:

2.4.1.1 The compressive strength of the concrete produced by the plant shall have a coefficient of variation of 0.15 or less and the average, compressive strength shall be equal to or greater than the specified requirement plus 2 1/2 standard deviations.

2.4.1.2 The air content of the concrete produced by the plant shall have a coefficient of variation of 0.18 or less, and the average air content shall not differ from the specified optimum value by more than one standard deviation.

2.4.1.3 The consistency of the concrete produced by the plant shall have a coefficient of variation of 0.20 or less, and the average consistency shall not differ from the specified optimum value by more than two standard deviations.

2.4.1.4 The plant shall maintain an adequate Quality Control Program for aggregate gradation.

2.4.2 LEVEL 2 QUALITY CONTROL

All plants which fail to meet one or more of the requirements specified in 2.4.1 will be considered to have LEVEL 2 Quality Control.

2.4.3 PHYSICAL PLANT-EVALUATION

District personnel will inspect and evaluate concrete plants in conformance with Section 1 of this memorandum. A copy of the inspection data, which is specified in Subsection 1.5, will be transmitted to the Materials Division immediately after the inspection is completed.

2.4.4 LEVEL OF QUALITY CONTROL - EVALUATION

The evaluation of the level of Quality Control maintained by concrete plants will be performed and maintained current by the Materials Division. The initial evaluation of the level of Quality Control will be based on an analysis of historical data. There after, tests for strength, entrained air, and consistency will be made by District personnel on random samples taken from plant production, and these test data will be used by the Materials Division to update the statistical parameters and maintain a current and valid evaluation of each plant's Quality Control level. The Materials Division will publish a list of concrete plants with their rating numbers, said publication to be updated monthly.

2.4.5 CLASS AI PLANTS - TEST AND INSPECTION REQUIREMENTS

Concrete from Class AI concrete plant shall be sampled and tested by District personnel on a random basis with the frequency specified in Subsection 700.03 of the Construction Manual.

Plant inspection at Class AI concrete plants shall be performed by District personnel on a random basis with the frequency specified in Subsection 700.03 of the Construction Manual.

A concrete delivery ticket (Form HL-411) shall be initiated and signed at the plant and accompany each delivery to the project.

2.4.6 CLASS A2 PLANTS - TEST AND INSPECTION REQUIREMENTS

Concrete for major Items from Class concrete plants shall be sampled and tested by District personnel on a project- by-project basis with the frequency specified in Subsection 700.03 of the Construction Manual.

Plant inspection at Class A2 concrete plants shall be performed by District personnel on a continual basis during the time that concrete for major items is being produced for State projects. Concrete for miscellaneous items (See 2.4.8) shall be sampled and tested with the same frequency required in 2.4.5, Class Al plants.

2.4.7 CLASS B PLANTS

Concretes purchased by a Contractor for use on State projects shall be supplied from Class Al or A2 plants. Concretes purchased through competitive bidding with Purchase order contracts shall be supplied from Class Al or A2 plants. (Class B plants are not considered to be eligible to compete with Class A plants in the furnishing of concrete to State projects).

In the event it is not practical to obtain small quantities of concrete for miscellaneous items (See 2.4.8) from a Class Al or A2 plant and a survey reveals that a Class B plant is conveniently situated with respect to the construction site, then a direct purchase of concrete by the Division from the Class B plant may be accomplished in conformance with standard procedures of the Purchasing Division of the Department of Finance and Administration. The direct purchase of concrete from Class B plants shall also be made to conform to the requirements set out in Subsection 2.5 entitled Quality Assurance OF DIRECT PURCHASE CONCRETES FROM CLASS B PLANTS. Plant inspection at Class B plants and the sampling, testing and documentation of concretes from Class B plants shall also conform to the requirements set out in Subsection 2.5.

2.4.8 SMALL QUANTITIES FOR MISCELLANEOUS ITEMS

Miscellaneous concrete shall be defined as relatively small quantities incorporated into items that will not adversely affect the traffic carrying capacity of a completed facility. Such items would not include any concrete intended for major structures permanent mainline or ramp pavements, or other structurally critical items.

The following items are suggested as a guideline in establishing miscellaneous concrete:

2.4.8.1 Sidewalks - not to exceed approximately 50 square meters per day.

2.4.8.2 Curb and gutter - Not to exceed approximately 150 lineal meters per day.

2.4.8.3 Concrete base course and concrete base course widening - Not to exceed approximately 50 square meters per day.

2.4.8.4 Paving, patching and temporary pavements.

2.4.8.5 Building floors and foundations.

2.4.8.6 Slope paving and headers.

2.4.8.7 Paved ditch.

2.4.8.8 Guardrail anchorages.

2.4.8.9 Metal pile shells.

2.4.8.10 Small culvert headwalls.

2.4.8.11 Fence posts.

2.4.8.12 Catch basins, manhole bases and inlets.

2.4.8.13 Sign, signal and light bases.

FLOW DIAGRAM NO. 2 is made a part of this memorandum and gives detailed information on the organization and operation of the Quality Assurance procedures.

2.5 QUALITY ASSURANCE OF DIRECT PURCHASE CONCRETES FROM CLASS B PLANTS

2.5.1 PURPOSE

The purpose of this instruction is to provide guidance in specifying direct purchase concretes and for inspection and testing direct purchase concretes from Class B plants so that a predetermined and acceptable level of Quality Assurance may be maintained by Division personnel. This instruction is set apart from the main directive in Subsection 2.4 because it is the intent to have concretes from Class B plants used in highway work only when it is not practical or economical to obtain concretes from Class A1 or A2 plants.

2.5.2 DEFINITION OF TERMS

2.5.2.1 Direct Purchase - Direct purchase is a formal procedure used by the Purchasing Division of Department of Finance and Administration to purchase supplied and equipment for government agencies (including the Division of Highways) when it is not practical or economical to use the procedure of competitive bidding. Direct purchase requisitions will always specify the name of the proposed supplier as well as product name, quantity, specifications, etc.

2.5.3 GENERAL DISCUSSION

When highway work requiring portland cement concrete is let to contract, the contract will normally allow for the Contractor to produce or procure the concrete in which event the concrete shall be supplied by a Class Al or A2 plant. If the Division should determine prior to letting work to contract that it would be impractical or uneconomical to obtain concrete from a Class Al or A2 plant but that it would be practical to obtain it from a Class B plant, then the Division may stipulate in the contract documents that the concrete will be supplied to the Contractor by the Division FOB site of work. In this event the purchase of concrete from a Class B plant shall conform to the requirements specified in Article 2.5.4.

When highway work requiring portland cement concrete is being done by Division forces and it is found to be impractical or uneconomical to obtain concrete from a Class Al or A2 plant but that it would be practical to obtain it from a Class B plant, then the purchase of concrete from a Class B plant shall be made to conform to the requirements of article 2.5.4.

2.5.4 INSTRUCTION

The purchase of portland cement concrete from a Class B plant will be permitted only after a field condition survey has been conducted and properly documented which indicates that it would be impractical and uneconomical to obtain concrete from a Class Al or A2 plant, and that a Class B plant does exist from which a direct purchase of concrete could practically and economically be made.

Procedures for making direct purchases of concrete shall be as prescribed by the Department of Finance and Administration. The method of specifying direct purchase concrete shall be as follows:

(1) Specify the class of concrete.

(2) Specify that the concrete mix design will be furnished by the Division.

(3) Specify that a Division inspector will be at the plant during the full time that concrete is being batched to direct the batching operation, and that batching shall not commence until the inspector is present.

(4) Specify that the inspector shall execute FORM OC-411 which will accompany each load of concrete to the site of the work.

In addition to the Quality Assurance activity performed at the plant, the Division will sample and test as deemed necessary all direct purchase order LOTS of concrete used in highway maintenance work.

FLOW DIAGRAM NO. 2 is made a part of this memorandum and gives detailed information on the organization and operation of the Quality Assurance procedures.

Gary L. Robson

Gary L. Robson, Director
Materials Control, Soils
and Testing Division

GLR:w

Attachments

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

GENERAL INFORMATION GUIDE FOR QUALITY ASSURANCE TESTING

1.0 PURPOSE

1.1 The purpose of the West Virginia Division of Highways (WVDOH) Technician and Inspector Certification Program is to improve the quality assurance of embankments, subgrades, base course, asphalt and Portland cement concrete by the certification of industry and Division of Highways personnel. This procedure is to establish guidelines for this purpose.

2.0 GENERAL

2.1 It is the Division's intent to conduct a cooperative program of training, study, and examination so that personnel of the producer, contractor, and the Division of Highways will be able to better assure, by their increased technical knowledge, the level of quality required by the governing specifications.

3.0 SCOPE

3.1 This procedure is applicable to all requirements, guidelines, and other support documents of the Division of Highways that reference conditions, methods, and levels of qualification specific to the Division of Highways training and certification program.

4.0 POLICIES AND ADMINISTRATION

4.1 Board of Certification - The Certification Program will be carried out in accordance with general policy guidelines established or approved by the State Highway Engineer. The State Highway Engineer will be advised by a Board composed of the following members:

1. Director of Materials Control, Soils and Testing Division
2. Director of Contract Administration Division
3. Director of Maintenance Division
4. Director Human Resources Division
5. Representatives of the Contractors Association of West Virginia
6. Representatives of West Virginia Hot-Mix Asphalt Materials Producers
7. Representatives of the West Virginia Aggregate Producers
8. Representatives of the West Virginia Cement Concrete Materials Producers

4.1.1 The Certification Board will meet upon call of the State Highway Engineer.

4.2 Administration - The program will be administered by the Director of the Materials Control, Soils and Testing Division (hereafter referred to as "Director"). The Director will have the assistance of an Implementation Committee appointed by the State Highway Engineer as follows:

1. Director of Materials Control, Soils and Testing Division
2. One senior representative of the Contract Administration Division
3. One senior representative of the Maintenance Division
4. A representative of the Human Resources Division of the Division of Highways

4.2.1 In addition to the above, the non-Division of Highways members (Section 4.1) of the Certification Board may jointly select representatives of producers and contractors to work with the Implementation Committee at such times and on such matters as the Director and the representatives mutually agree. These representatives shall not be candidates for certification.

4.2.2 The Implementation Committee will meet upon call of the Director, or person authorized by the Director.

4.2.3 A Program Coordinator is to be recommended by the Implementation Committee and selected by the State Highway Engineer. The Committee will be assigned to assist the Director in administering the program and to handle planning, administration, and coordinating functions as may be delegated within the scope of appropriate Division of Highways directives.

5.0 REQUIREMENTS

5.1 Where applicable, quality control representatives of a contractor or producer will be certified in one (or more) of the certifications listed in Section 6.0 depending upon the individual's duties or responsibilities. Responsibilities and qualification requirements are listed in appropriate support documents such as Materials Procedures, Quality Control Plans and others.

5.2 For purposes of the Division's Quality Assurance program, a non-Highways Division certified technician/inspector represents the company of which he/she is a full-time employee on the project, owner, or partner (as defined by the Federal Wage and Hour Legislation). If said company has subsidiary or affiliated organizations, each organization will be required to have its own certified technicians/inspectors where applicable unless the State Highway Engineer makes an exception. Exceptions will be granted only when it can be proven that the certified technician/inspector actually performs the duties of the technician/inspector for all of the subsidiary or affiliated organizations.

5.3 Designated Highways Division personnel will be certified where applicable in one (or more) of the certifications listed in Section 6.0 depending upon the individual's duties or responsibilities.

6.0 CERTIFICATIONS

6.1 All certifications listed in the sections below require written examinations. Some of the listed certifications require a practical examination after successful completion of the written examination. It is the responsibility of the applicant to determine which certification is applicable to his/her assignment. Following is a description of the certifications listing relevant information about each:

6.2 AGGREGATE CERTIFICATIONS

6.2.1 Aggregate Inspector - The written examination for an Aggregate Inspector consists of the following areas:

- Aggregate Specifications and Procedures
- Aggregate Fundamentals
- Sampling, Control, and Inspection of Aggregates
- Aggregate Testing

After successful completion of the written examination, the applicant will be required to pass a practical examination consisting of his/her demonstration of testing common to normal aggregate quality requirements. Certification as an Aggregate Inspector qualifies the employee, either Industry or Division, to perform sampling and/or testing of aggregates relevant to the quality control program or acceptance program respectively.

6.2.2 Aggregate Sampling Inspector - The written examination for an Aggregate Sampling Inspector consists of the following areas:

- Sampling Fundamentals
- Sampling Methods and Equipment

The Aggregate Sampling Inspector requires only the successful completion of the written examination; no practical examination is required. Certification as an Aggregate Sampling Inspector qualifies the employee, either Industry or Division, to perform sampling of aggregates relevant to the quality control program or acceptance program respectively.

6.3 COMPACTION CERTIFICATIONS

6.3.1 Compaction Inspector - The written examination for a Compaction Inspector consists of the following areas:

- Specifications
- Compaction Test Procedures
- Radiation Safety and Nuclear Gauge
- Test Procedure Problems

After successful completion of the written examination, the applicant will be required to pass a practical examination demonstrating his/her proficiency in using the testing equipment. Certification of the Compaction Inspector qualifies the employee, either Industry or Division, to conduct tests on all construction materials that require compaction testing.

6.4 CONCRETE CERTIFICATIONS

6.4.1 Concrete Technician - The written examination for a Concrete Technician consists of the following areas:

- Fundamentals
- Sampling and Testing
- Control and Inspection
- Mix Proportioning and Adjustment

The Concrete Technician requires only the successful completion of the written examination; no practical examination test is required. Certification of the Concrete Technician qualifies the employee, either Industry or Division, to make plant and mix adjustments, proportioning, and other duties.

6.4.2 Concrete Inspector - The written examination for a Concrete Inspector consists of the following areas:

- Fundamentals
- Sampling and Testing
- Control and Inspection
- Specifications

After successful completion of the written examination, the applicant will be required to pass a practical examination demonstrating his/her proficiency in conducting tests common to concrete quality control. Certification as a Concrete Inspector qualifies the employee, either Industry or Division, to perform sampling and/or testing of concrete relevant to the quality control program or acceptance program respectively.

6.5 HOT-MIX ASPHALT CERTIFICATIONS

6.5.1 Hot-Mix Asphalt Technician - The written examination for a Hot-Mix Asphalt Technician consists of the following areas:

- Fundamentals
- Sampling and Testing
- Control and Inspection
- Mix Proportioning and Adjustment

After successful completion of the written examination, the applicant will be required to pass a practical examination demonstrating their proficiency in conducting tests common to Hot-Mix Asphalt quality control. Those persons, who have already completed certification requirements for the Hot-Mix Asphalt Inspector program (see Section 6.5.3), and have kept their certification updated, will not be required to retake the practical examination. Certification of the Hot-Mix Asphalt Technician qualifies the employee, either Industry or Division, to take HMA samples, perform quality control or quality assurance testing on plant produced HMA, make plant and mix adjustments, aggregate proportioning, and other duties.

6.5.2 Asphalt Field Technician – The written examination for an Asphalt Field consists of the following areas:

- Surface Preparation
- Mix Delivery and Placement
- Joint Construction
- Pavement Compaction and Compaction Testing

The successful completion of the written examination is the only mandatory requirement for the Asphalt Field Technician. No practical examination test is required; however, see Section 6.5.2.1 for additional information regarding asphalt pavement density testing. Certification as an Asphalt Field Technician qualifies the employee, either Industry or Division, to oversee or inspect asphalt pavement construction. In addition, the class hand-out material is a valuable reference tool for each stage of the construction process. The required radiation safety training is not included in this class.

6.5.2.1 For those Asphalt Field Technicians that wish to become certified to perform nuclear density testing of asphalt pavements, they must be evaluated by qualified District personnel on the first WVDOH paving project in which they perform this testing. The District personnel will make the decision as to whether or not the technician is correctly conducting the nuclear density tests in accordance with Division specifications. The District will also complete an evaluation form and send it to the Materials Control, Soils & Testing Division for processing. A technician that does not demonstrate proper nuclear density testing techniques shall not be allowed to continue testing on the project. They must be replaced by another qualified technician. Anyone who does not meet the evaluation standards must provide proof of Division approved training before another evaluation will be conducted.

6.5.3 Hot-Mix Asphalt Inspector – The Hot-Mix Asphalt Inspector certification will no longer be offered by the WVDOH. Those persons who have the Asphalt Inspector certification, but do not have the Hot-Mix Asphalt Technician certification, will be allowed to continue HMA sampling and testing activities for the WVDOH, and their certification will be renewable on a regular basis. For those who have both of these certifications, the Hot-Mix Asphalt Inspector certification will not be renewed since it will no longer be required.

7.0 TRAINING

7.1 Training - The Division of Highways, contractors, and producers will sponsor courses of instruction consisting of schools and seminars to help prepare personnel for certification under one or more of these certification programs. To the extent possible, these courses of instruction will be joint efforts of the industry and WVDOH. Nothing in this document shall be interpreted to prohibit any party from conducting courses of instruction for their personnel to assist in preparation for these exams.

7.2 The purpose of the schools is to provide helpful information and instruction for persons preparing to take the technician/inspector examinations. These courses are designed to provide instruction for persons with a basic foundation in the subject matter.

8.0 EXAMINATIONS

8.1 Examinations, both written and practical, will be coordinated by the Materials Control, Soils & Testing Division of the Division of Highways. The locations and dates of the examinations will be announced at least two weeks prior to being given. The examinations may be held on a regional basis when feasible. All written examinations will be a one-part, 'open-book' type, with a maximum time limit of three hours. Practical examinations require performance of the tests required by the specifications for the material type involved.

8.2 To pass the written examinations, the applicant must obtain a score of at least 70 percent. There will be two written examinations per certification topic each year prior to May.

8.3 After the applicant passes the written examination, they will have two attempts within a 12 month period to pass the practical exam.

8.3.1 A third written examination shall be offered per certification in July for a fee of $250.00. This examination is limited to applicants who have not previously taken the written examination more than once within the calendar year. An applicant may only test twice per certification in a calendar year. A practical examination will be offered for those individuals who pass the third examination.

8.4 Certificate Non-Transferable - The status of the certification for a technician or an inspector is not transferable and is valid only for the quality control procedures designated by the bearer's certificate.

8.5 Revocation of Certificate - If at any time a Division of Highways, contractor's, producer's, or supplier's technician or inspector is found to have altered or falsified test reports or is found to have improperly performed tests or reported their results, the individual's certification may be rendered invalid by the State Highway Engineer upon recommendation of the Implementation Committee and/or the Board.

8.6 Renewal and Certification - Certification will be renewed every five (5) years. General guidance and information for renewal will be recommended by the Board as required by the State Highway Engineer. All renewals of certification shall be for a five-year period, and shall terminate on December 31 of the fifth-calendar year after renewal has been made.

8.6.1 The responsibility for applying for re-certification shall lie with the certified individual. The Division of Highways will attempt to contact a person by mail at their last known address. Such contact will be made within sufficient time to notify a person that their certification is about to expire. It is, however, the responsibility of the individual to inform the Division of Highways Human Resources Division of his/her current address.

8.6.2 Applications for re-certification shall be on a standard form prepared by the Division of Highways and should include a chronological history of the candidates work within the area in which certification has been made. Such history will include only those assignments pertinent to this field during the five-year period for which the person was certified. The purpose of including this work history within this field is to permit the Implementation Committee or other party so designated by the State Highway Engineer to determine if the applicant for renewal had sufficient contact within the area in order to obtain renewal without having to retake the examination.

8.6.3 The above application will be notarized (Section 8.6.3).

8.6.4 The Implementation Committee or other designated party shall establish internal criteria for renewal and shall recommend to the State Highway Engineer disposition of each applicant. The State Highway Engineer may request the Board to review applications as required.

8.6.5 Upon obtaining renewal of certification, a renewal card shall be issued.

8.7 Application for Certification - Applications for certification will be directed to the Human Resources Division of the Division of Highways.

9.0 FUNCTIONS AND RESPONSIBILITIES

9.1 Contractor or Producer - The producer and contractor will be responsible for product control of all materials during the handling, blending, and mixing operations. The contractor and producer also will be responsible for the formulation of a design mix that will be submitted to the Division of Highways for approval.

9.1.1 Technician/Inspector - A Quality Control representative of a contractor or producer should be a certified technician/inspector as outlined in Section 5.0 and whose responsibilities may include such duties as proportioning and adjusting the mix, sampling and testing the product, and preparing control charts.

9.2 The Division of Highways - The Division of Highways is responsible for all acceptance decisions.

9.2.1 District Materials Supervisor - District Materials activities are the responsibility of the District Materials Supervisor.

9.2.2 Division Technicians and Inspectors - Division of Highways technicians and inspectors will be assigned as necessary to carry out the required acceptance decision activities. These employees will not issue instructions to the contractor or producer regarding process control activities. However, the Division of Highways representatives have the responsibility to question, and where necessary to reject, any operation or sequence of operations, which are not performed in accordance with the contract documents.

Aaron C Gillespie

Aaron C. Gillispie, P.E., Director
Materials Control, Soils and Testing Division

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

GUIDE FOR QUALITY CONTROL AND ACCEPTANCE REQUIREMENTS FOR PORTLAND CEMENT CONCRETE

1.0 PURPOSE

1.1 To establish minimum requirements for Contractor's quality control system and the Division's Acceptance Plan. It is intended that these requirements be used as a procedural guide in detailing the inspection, sampling, and testing deemed necessary to maintain compliance with the specification requirements.

2.0 REQUIREMENTS

2.1 General Requirements

The contractor shall provide and maintain a quality control system that will provide reasonable assurance that all materials and products submitted to the Division for acceptance will conform to the contract requirements whether manufactured or processed by the Contractor or procured from suppliers, subcontractors, or vendors. The contractor shall perform or have performed the inspections and tests required to substantiate product conformance to contract document requirements and shall also perform or have performed all inspections and tests otherwise required by the contract. The Contractor's quality control inspections and tests shall be documented and shall be available for review by the Engineer throughout the life of the contract. The Contractor shall maintain standard equipment and qualified personnel as required by the Specifications to assure conformance to contract requirements. Procedures will be subject to the review of the Division before the work is started.

2.2 Quality Control Plan(s):

2.2.1 The contractor shall prepare a Quality Control Plan detailing the type and frequency of inspection, sampling, and testing deemed necessary to measure and control the various properties of materials and construction governed by the Specifications. As a minimum, the sampling and testing plan should detail sampling location, sampling techniques, and test frequency to be utilized. Quality control sampling and testing performed by the Contractor may be utilized by the Division for acceptance. The Quality Control Plan shall be submitted in writing to the Engineer at the preconstruction conference.

2.2.2 The Plan shall identify the personnel responsible for the Contractor's quality control. This should include the company official who will act as liaison with Division personnel, as well as the Certified Portland Cement Concrete Technician who will direct the inspection program. Certified Portland Cement Concrete Inspectors responsible for sampling and testing of the plastic as well as the hardened concrete shall also be listed on this Quality Control Plan.

2.2.3 The Class or Classes of concrete involved will be listed separately. If existing mix designs are to be utilized, the Mix Design Numbers shall be listed.

2.2.4 Process control sampling, testing, and inspection should be an integral part of the contractor's quality control system. In addition to the above requirements, the Contractor's quality control system should document the process control requirements shown in Table 1. The process control activities shown in Table 1 are considered to be normal activities necessary to control the production and placing of a given product or material at an acceptable quality level. To facilitate the Division's activities, the Contractor, as per ML-25, shall retain all completed gradation samples until further disposition is designated by the Division.

2.2.5 If the District (in which the Project is located) permits, and if the Contractor and Concrete Plant both elect to do so, the Contractor may submit a Quality Control Plan for field operations, and the Concrete Plant may submit a separate Quality Control Plan for plant operations as outlined below.

2.2.5.1 The Quality Control Plan for plant operations shall be submitted to the District (in which the Concrete Plant is located) by the Plant on an annual basis. This Plant Quality Control plan shall be valid for the entire year and shall include all quality control information pertaining to operations at the plant. If there are any personnel or other quality control related changes at the Plant throughout the course of the year, the Plant shall submit an addendum to this annual Plant Quality Control Plan. If this Plant Quality Control Plan is deemed adequate, the District shall issue it a laboratory approval number separate from any Field Quality Control Plan.

2.2.5.2 A Quality Control Plan for field operations shall be submitted to the District (in which the Project is located) by the Contractor for each project. This Field Quality Control Plan shall include all quality control information pertaining to operations in the field, and shall include a copy of the approved Plant Quality Control Plan for the concrete plant that is supplying the concrete for the subject project. The Contractor shall state in the Field Quality Control Plan that he (she) has reviewed the Plant Quality Control Plan and whether or not he (she) concurs with it. If this Field Quality Control Plan is deemed adequate, the District shall issue it a separate laboratory approval number from the Plant Quality Control Plan. Even though the two Quality Control Plans may be submitted separately, the Contractor is ultimately responsible for ensuring that all quality control requirements and operations (both plant and field) are being upheld.

2.2.6 All sampling and testing shall be in accordance with the methods and procedures required by the specifications, and measuring and testing equipment shall be standard and properly calibrated as per the specified test procedure. If alternative sampling methods and procedures and inspection equipment are to be used, they shall be detailed in the Quality Control Plan.

2.2.6.1 When calculating the compressive strength of concrete cylinders in accordance with AASHTO T22, the following procedure shall be used:

$$CS = \frac{ML}{0.25 \times \pi \times D^2}$$

Where:
CS = Compressive strength of the specimen
ML = Maximum load carried by the specimen during the test
Π = Mathematical constant PI
D = Diameter of the cylinder being tested (in accordance with AASHTO T 22)

Note: The calculation for CS shall be performed in one continuous step (without any rounding), either by the testing machine, or by calculating device, and only the final value (CS) is permitted to be rounded (to the accuracy specified in AASHTO T 22). The value for Π shall be the manufacturer's pre-programmed value in a calculating device or the testing machine.

2.3 <u>Miscellaneous Concrete:</u>

The contractor is not required to perform the process control testing required by Part C of Table 1 on miscellaneous concrete (as defined in section 2.3.1), provided that the concrete in question is being supplied by an A1 or A2 plant (as defined in IM-18), and provided that the requirements of section 2.3.2 are met for each project on which the reduced testing of miscellaneous concrete is applied.

2.3.1 Miscellaneous concrete shall be defined as relatively small quantities, not exceeding 25 yd^3 (19 m^3) per day, incorporated into items that will not adversely affect the traffic carrying capacity of a completed facility. Such items would not include any concrete intended for major structures, permanent mainline or ramp pavements, or any other structurally critical items.

The following items are suggested as a guideline in establishing items that may be categorized as miscellaneous concrete:
Note: Concrete testing for certain items below is waived, in some cases, by the referenced section of the specifications.

1. Sidewalks
2. Curb and Gutter
3. Concrete base course and concrete base course widening
4. Pavement patching, temporary pavements, and pipe crossings
5. Building floors and foundations
6. Slope paving and headers
7. Paved ditch or gutter
8. Guardrail anchorages (See section 715.12)
9. Metal pile shells (See section 614.5)
10. Small (less than 36" diameter) culvert headwalls
11. Fence posts (See section 715.12)
12. Catch basins, manhole bases, inlets, and junction boxes (and adjustments of such items) not located in the roadway
13. Foundations for breakaway supports
14. Thrust blocks
15. Utility trench fills
16. Cast-in-place survey markers
17. Slopewalls for under drain outlet pipes

2.3.2 A minimum of ten samples per month will be randomly selected from plant production (for each project receiving concrete from the subject plant) and tested for compressive strength, air content, and consistency. Yield will be checked on one of the above samples. On a minimum of four of the ten samples outlined above, the Division will observe the batching operation at the plant (that is producing the concrete to be sampled) and check the operational control. In the event that production is estimated to be insufficient to fulfill the above requirements, a minimum of one sample per two days of production (for the same project) will be tested (beginning on the first day of production) for compressive strength, air content, and consistency. One yield test will be conducted per ten samples. On a minimum of forty percent of the samples outlined above, the Division will observe the batching operation at the plant (that is producing the concrete to be sampled) and check the operational control, except that not more than four such checks will be required in any one month.

2.3.3 Laboratory number 1345635 shall be used by the Districts for documentation and acceptance purposes for quantities of concrete designated as miscellaneous concrete.

2.4 Documentation:

The Contractor shall maintain adequate records of all inspections and tests. The records shall indicate the nature and number of observations made, the number and type of deficiencies found, the quantities approved and rejected, and the nature of corrective action taken as appropriate. The Contractor's documentation procedures will be subject to the review and approval of the Division prior to the start of the work and to compliance checks during the progress of the work.

2.4.1 Charts and Forms:

All conforming and non-conforming inspections and test results shall be kept complete and shall be available at all times to the Division during the performance work. Forms shall be on a computer-acceptable medium where required. Batch ticket data shall be documented in accordance with the applicable section of MP 601.03.50, with a copy to be submitted to the District Materials Section within 72 hours of the concrete placement. Gradation data shall be documented on WVDOH form T300 using the material codes listed in the online computer systems user guide. The original gradation data shall be submitted to the District Materials Section within 72 hours of obtaining the gradation sample. Test data for Portland cement concrete shall be charted in accordance with the applicable requirements of MP 601.03.52. Gradation test data shall be plotted in accordance with the applicable requirements of MP 300.00.51. The Contractor may use other types of control charts as deemed appropriate. It is normally expected that testing and charting will be completed within 48 hours after sampling. The Contractor shall also ensure that all Material Suppliers prepare and submit the HL-441 form (weekly supplier report) in a timely manner.

2.4.2 All charts and records documenting the Contractor's quality control inspections and tests shall become property of the Division upon completing of the work.

2.4.3 Batch Tickets

Each batch of Structural Concrete, including miscellaneous concrete (as defined in section 2.3.1), delivered at the project shall be accompanied by one batch ticket with all of the items of information listed in section 2.4.4 pre-printed on the ticket. In the case of Portland Cement Concrete Pavement, each batch of concrete delivered at the project on which a test in accordance with Table 1 is to be performed shall be accompanied by a batch ticket. This batch ticket shall have all of the items listed in section 2.4.4 pre-printed on the ticket unless nonagitator trucks or truck agitators are used. In this case, the batch ticket shall have all of the items listed in section 2.4.5 pre-printed on the ticket.

2.4.4 All batch tickets for Structural Concrete and Portland Cement Concrete Pavement Concrete transported by truck mixers shall have all of the following items pre-printed on the ticket:
Source Code, Source Name, Source Location, Mix Design Number, Date, Sequence Number, Volume (yd^3/m^3), Time Batched, Time Unloaded, Authorization Number, Material Code, Material Name, Water Allowed (Gallon/Liter), Water at Plant (Gallon/Liter), Water at Job (Gallon/Liter), Weight Cement (lb/kg), Weight Pozzolan (lb/kg), Temperature ($^oF/^oC$), Cylinder I.D., Initial Counter, Final Counter, Target Consistency (in/mm), Actual Consistency (in/mm), Target Air (%), Actual Air (%), Truck Number

2.4.5 All batch tickets for concrete delivered by means of nonagitator trucks or truck agitators shall have all of the following items pre-printed on the ticket:
Source Name, Mix Design Number, Date, Sequence Number, Volume (yd^3/m^3), Time Batched, Time Unloaded, Authorization Number, Material Code, Material Name, Water Allowed (Gallon/Liter), Water at Plant (Gallon/Liter), Weight Cement (lb/kg), Weight Pozzolan (lb/kg), Temperature ($^oF/ ^oC$), Target Consistency (in/mm), Actual Consistency (in/mm), Target Air (%), Actual Air (%), Truck Number

2.4.6 The batch ticket in the case of either type of concrete shall be a pre-printed batch ticket prepared by the plant. This ticket may be either computer generated or a standard pre-printed form with blank spaces provided in which all of the required data shall be recorded. The data items listed above that are completed in the field (such as Time Unloaded, Actual Consistency, etc.) must have a space on the batch ticket for completion. Volume is to be reported to the nearest 0.01 yd3 (0.01 m3). Consistencies are to be reported to the nearest 0.25 inch (6 mm). Target and Actual Air are to be reported to the nearest 0.1% (to the nearest 0.25% if the volumetric method is used).

2.5 Corrective Action:

The Contractor shall take prompt action to correct conditions, which have resulted, or could result, in the submission to the Division of materials and products, which do not conform to the requirements of the Contract documents.

2.6 Non-Conforming Materials:

The contractor shall establish and maintain an effective and positive system for controlling non-conforming material, including procedures for its identification, isolation and disposition. Reclaiming or reworking of non-conforming materials shall be in accordance with procedures acceptable to the Division. All non-conforming materials and products shall be positively identified to prevent use, shipment, and intermingling with conforming materials and products. Holding areas, mutually agreeable to the Division and the Contractor shall be provided by the Contractor.

3.0 ACCEPTANCE SAMPLING AND TESTING

3.1 Acceptance sampling and testing is the responsibility of the Division. Quality control tests by the Contractor may be used for acceptance.

3.2 The Division shall sample and test for applicable items completely independent of the contractor at a frequency equal to approximately ten (10) percent of the frequency for testing given in the approved Quality Control Plan. Witnessing the contractor's sampling and testing activities may also be a part of the acceptance procedure, but only to the extent that such tests are considered "in addition to" the ten (10) percent independent tests.

3.3 Results from independent tests conducted by the Division for gradation, entrained air, consistency, and strength will be plotted on the Contractor's quality control charts with a red circle, but are not to be included in the moving average. When the Contractor's tests are witnessed, the results are circled on the control chart in red, and are to be included in the moving average calculations.

3.4 Results from both independent tests and witnessed tests will be evaluated in accordance with MP 700.00.54. If a dissimilarity is detected, an investigation shall be immediately initiated to determine the cause of the dissimilarity.

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Attachments

Table 1

CONTRACTOR'S PROCESS CONTROL REQUIREMENTS

STRUCTURAL CONCRETE AND
PORTLAND CEMENT CONCRETE PAVEMENT

		Minimum Frequency*
A.	PLANT AND TRUCKS	
	1. Mixer Blades	Prior to Start of Job and Weekly
	2. Scales	
	a. Tared	Daily
	b. Calibrate	Prior to Start of Job
	c. Check Calibration	Weekly
	3. Gauges and Meters - Plant and Truck	
	a. Calibrate	Yearly
	b. Check Calibration	Weekly
	4. Admixture Dispenser	
	a. Calibrate	Prior to Start of Job
	b. Check Operation and Calibration	Daily
B.	AGGREGATES	
	1. Fine Aggregate	
	a. Gradation	Per section 601.3.2.4 of the specifications
	b. Moisture	Daily

2. Coarse Aggregates

a. Gradation	Per section 601.3.2.4 of the specifications
b. Percent Passing No. 75mm	Daily
c. Ā for Combined Coarse Aggregates, Fine Aggregates, and Cement	Per section 601.3.2.4 of the specifications
d. Moisture	Daily

C. PLASTIC CONCRETE

1. Entrained Air Content

Pavement Concrete	One per 500 yd^3 (380 m^3) or fraction thereof, with a minimum of two per day
Structural Concrete (except bridge superstructure)	One per 100 yd^3 ($75m^3$) or fraction thereof, with a minimum of one per 1/2 Day of Operation
Bridge Superstructure	One per Batch

2. Consistency

Pavement Concrete	One per 500 yd^3 (380 m^3) or fraction thereof, with a minimum of two per day
Structural Concrete (except bridge superstructure)	One per 100 yd^3 ($75m^3$) or fraction thereof, with a minimum of one per 1/2 Day of Operation
Bridge Superstructure	One for first batch and one for every fifth batch thereafter

3. Temperature — Per Specifications

4. Yield

Pavement Concrete	Per section 501.3 of the specifications and one for each five days of operation after the first five days of operation
Structural Concrete	Per section 601.3.2.3 of the specifications and one for each ten sets of cylinders after the first ten

5. Compressive Strength**

Pavement Concrete	Per section 501.4.4 of the specifications
Structural Concrete	For each class concrete delivered and placed on a calendar day from a single supplier, one set of concrete cylinders for each 100 yd^3 ($75m^3$) or fraction thereof. ***

*Frequency for Process Control will vary with the size and type of aggregate or mixture and the batch-to-batch variability of the item.

**The use of Materials Procedure MP 711.03.31, Predicting Potential Cement Concrete from Early Breaks, is encouraged due to the extensive and timely information furnished by this method.

***All cylinders shall be made, cured, and shipped to the Laboratory in accordance with AASHTO T 23 and MP 601.04.20. They shall be tested in accordance with AASHTO T 22 and section 601.4.4 of the Standard Specifications.

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

STANDARD METHOD FOR DETERMINATION OF Ā OF THE TOTAL SOLIDS IN PORTLAND CEMENT CONCRETE

1.0 PURPOSE

1.1 To establish a procedure for determining the Ā of the total solids contained in portland cement concrete.

1.2 To establish a uniform definition of Ā.

2.0 SCOPE

2.1 This procedure shall apply in all cases where the specification requires the determination of Ā of the total solids in portland cement concrete.

3.0 DEFINITIONS

3.1 Ā (A-Bar) – A factor that characterizes the gradation of an aggregate. The size of the factor is very highly correlated with the aggregate surface area. The Ā factor is used as a control in concrete mix designs.

4.0 PROCEDURE

4.1 Since the solids contained in a portland cement concrete mix consist of coarse aggregate, fine aggregate, and portland cement, this procedure will address the determination of Ā of these solids in combination.

4.1.1 The mass of the solid materials used in the mix proportions shall be used to determine the percent of each constituent material in the total solids.

4.1.1.1 Determine the total mass of solids:

$M_{ca} + M_{fa} + M_c = M_t$

Where:

M_{ca} = mass of coarse aggregate (SSD) used in one cubic yard (meter) of concrete.

M_{fa} = mass of fine aggregate (SSD) used in one cubic yard (meter) of concrete.

M_c = mass of cement used in one cubic yard (meter) of concrete.

M_t = total mass of solids in one cubic yard (meter) of concrete.

4.1.1.2 Determine the fractional part of each solid (solid fraction):

$\frac{M_{ca}}{M_t}$ = fractional part of coarse aggregate in the mix

$\frac{M_{fa}}{M_t}$ = fractional part of fine aggregate in the mix

$\frac{M_c}{M_t}$ = fractional part of cement in the mix

4.1.2 Determine the gradation of each of the individual materials using standard procedures with the following modifications.

4.1.2.1 When determining the fine aggregate gradation, include Standard Sieve sizes 3/8 inch (9.5 mm), No. 4 (4.75 mm), No. 8 (2.36 mm), No. 16 (1.18 mm), No. 30 (600 µm), No. 50 (300 µm), No. 100 (150 µm), and No. 200 (75 µm).

4.1.2.2 When determining the coarse aggregate gradation, all material passing the smallest specification sieve shall be sieved through either eight or twelve inch sieves. Only a minor amount of material will be retained on any sieves above the No. 200. This amount of material is considered to be insignificant and is added to the amount retained on the No. 200 sieve.

4.1.3 Determine the Solid Ā's. The Solid Ā of each constituent shall be determined by adding the cumulative percentages by mass of material passing each of Standard Sieve sizes 1 1/2 inch (37.5 mm), 3/4 inch (19 mm), 3/8 inch (9.5 mm), No. 4 (4.75 mm), No. 8 (2.36 mm), No. 16 (1.18 mm), No. 30 (600 µm), No. 50 (300 µm), No. 100 (150 µm), and No. 200 (75 µm) and dividing by 100.

4.1.4 Determine the Ā of each of the solids using the fractional parts (solid fractions) from 4.1.1.2 and the Solid Ā of each constituent from 4.1.3.

$\bar{A}_{ca}$ = fractional part of coarse aggregate x Solid Ā of coarse aggregate

$\bar{A}_{fa}$ = fractional part of fine aggregate x Solid Ā of fine aggregate

$\bar{A}_{c}$ = fractional part of cement x Solid Ā of cement

Where:

$\bar{A}_{ca}$ = Ā of coarse aggregate
$\bar{A}_{fa}$ = Ā of fine aggregate
$\bar{A}_{c}$ = Ā of cement

4.1.5 Determine the Ā of the Total Solids:

Ā Total Solids = $\bar{A}_{ca} + \bar{A}_{fa} + \bar{A}_{c}$

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Attachments

EXAMPLE OF CALCULATIONS
Ā TOTAL SOLIDS

1. Total mass of solids in one cubic yard (meter) of concrete:

M_{ca} = Mass of SSD Coarse Aggregate = 1800 lb. (816 kg)

M_{fa} = Mass of SSD Fine Aggregate = 1100 lb. (499 kg)

M_c = Mass of cement = 600 lb. (272 kg)

M_t = Total mass of Solids

$M_t = M_{ca} + M_{fa} + M_c$

M_t = 1800 lb. (816 kg) + 1100 lb. (499 kg) + 600 lb. (272 kg) = 3500 lb. (1587 kg)

2. Fractional part of each solid:

$$\frac{M_{ca}}{M_t} = \frac{1800\text{ lb. } (816\text{ kg})}{3500\text{ lb. } (1587\text{ kg})} = 0.514$$

$$\frac{M_{fa}}{M_t} = \frac{1100\text{ lb. } (499\text{ kg})}{3500\text{ lb. } (1587\text{ kg})} = 0.314$$

$$\frac{M_c}{M_t} = \frac{600\text{ lb. } (272\text{ kg})}{3500\text{ lb. } (1587\text{ kg})} = 0.171$$

3. Determination of the Solid $\bar{A}$ of each constituent:

PERCENT PASSING

Sieve Size		Coarse Aggregate	Fine Aggregate	Cement
1 1/2 in.	(37.5 mm)	100	100	100
3/4 in.	(19.0 mm)	84	100	100
3/8 in.	(9.5 mm)	21	100	100
No. 4	(4.75 mm)	2	98	100
No. 8	(2.36 mm)	1	83	100
No. 16	(1.18 mm)	0	65	100
No. 30	(600 μm)	0	48	100
No. 50	(300 μm)	0	13	100
No. 100	(150 μm)	0	3	100
No. 200	(75 μm)	0.5	1.5	100
Totals		208.5	611.5	1000
Solid $\bar{A}$'s		2.08	6.12	10

4. Determine the $\bar{A}$ of each of the solids:

$$\bar{A}_{ca} = 0.514 \times 2.08 = 1.07$$
$$\bar{A}_{fa} = 0.314 \times 6.12 = 1.92$$
$$\bar{A}_{c} = 0.171 \times 10 = 1.71$$

5. Determine the $\bar{A}$ of the Total Solids:

$$\bar{A}\text{ Total Solids} = 1.07 + 1.92 + 1.71 = 4.70$$

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

PROCEDURAL GUIDELINES FOR MAINTAINING CONTROL CHARTS FOR PORTLAND CEMENT CONCRETE

1.0 PURPOSE

1.1 To establish guidelines for developing and maintaining control charts to evaluate consistency, percent entrained air, strength characteristics, and the total solids A of portland cement concrete.

2.0 SCOPE

2.1 These procedures shall be applicable in all instances in which they can be reasonably and logically applied. For consistency, air, and strength, the applicability will normally depend on the quantity of material used, the continuity of delivery, etc. Control charts for total solids A shall be maintained for all concrete designs used on state work by a concrete producer.

3.0 GENERAL PROCEDURE

3.1 Control charts will be maintained at locations where the test samples are taken.

3.2 Control charts will be prepared on a 10 x 10 cross section paper with a width of approximately 560 mm for the sheet presenting the charts for consistency, percent entrained air, and strength characteristics. A separate sheet of sufficient width shall be used to accommodate the control charts for the total solids A for concrete mix designs. A chart length of approximately 760 mm should be displayed at all times. When standard cross section sheets are used, the most recent sheet will be displayed and the previous sheets will be placed chronologically in a holder.

3.3 Charts for consistency, air, and strength shall have the item number and/or description of the material noted on the top of the chart and will be visible at all times. charts will have the design number and class of concrete visible at all times.

4.0 CHART PREPARATION

4.1 At the beginning and end of each sheet (or the length of the displayed portion), vertical red lines will be drawn between the limits of the specification or tolerance; an arrow will be placed at the end of the vertical lines; the specification limits will be written above and below the arrows and the name of the property being graphed and the scale will be indicated between the limits on the left edge of the chart. See Appendix 1 and 2 for typical arrangements.

4.2 Scale

4.2.1 Consistency - One division of vertical scale will represent 5.0 mm of slump, or 5.0 mm of ball penetration (25 mm - 50 mm).

4.2.2 Air Content - One division of vertical scale will represent one-tenth of a percentage point of entrained air (25 mm - 1%).

4.2.3 Strength - One division of vertical scale will represent 1 MPa (25 mm = 10 MPa) compressive or 69 KPa (25 mm = 1 MPa) flexural strength.

4.2.4 Total solids A - One division of vertical scale will represent .01 (25 mm = 0.1) when the coarse aggregate size is 57, 7, 78, or 8 and .02 (25 mm = 0.2) when the coarse aggregate size is Number 3.

4.3 Plotting Test Data

4.3.1 Symbols and Color Code - Individual test values will be plotted in blue using the symbol " O ", with the circle being approximately 2.5 mm in diameter. Average test values for consistency, percent air, and strength as well as the averages of consecutive five test values for total solids A shall be plotted in red using the symbol " □ ", with the square being approximately 2.5 mm on each side. Independent Assurance test values developed by the Division, including record samples, will be plotted in green using the symbol " △ " with the sides of the triangle being approximately 2.5 mm.

4.3.2 Arrangement of Data - All data developed on a production day will be plotted on one heavy, vertical line, however, when two or more individual test values developed on the same production day have the same magnitude, the symbols may be plotted side-by-side on the same horizontal division line. All test data for a characteristic developed on a production day, exclusive of any independent testing conducted by the Division, will be averaged, and the average value plotted on the same vertical line as the individual test values. When an average value and an individual test value have the same magnitude, the plotted symbols may be superimposed.

4.3.3 When individual test values fall outside the specification limits, an arrow will be placed on the plotted symbol pointing in the direction of the specification limit.

4.3.4 As test data are developed on following production days, it will be plotted on successive heavy vertical lines, 25 mm apart, progressing from left to right across the control chart. As successive averages for consistency, percent air, and strength characteristic are plotted, the symbol " □ " will be connected with a heavy red solid line. For total solidsA control chart the moving average is the average of five consecutive test values and is determined by starting with the fifth test value and averaging it with the four preceding test values. The moving average of five symbol " □ " will be connected with a heavy red solid line. Individual test values will have the symbol " O " connected with a dashed blue line.

4.3.5 At the bottom of the cross section paper and immediately to the left of the heavy vertical line on which the test data are plotted, the date of sampling and initials of the individual plotting the test data will be recorded.

5.0 FAILING TESTS

5.1 When individual test values fall outside the specification limits, this information will immediately be made available to the supervisory personnel of both the Contractor and the Division.

5.2 Should the moving average of five fall outside the design mixA tolerance, action required by the Specification will be taken. When appropriate action has been taken to bring theA back within tolerance the first individual production sample that is within tolerance shall be used to start a new moving average.

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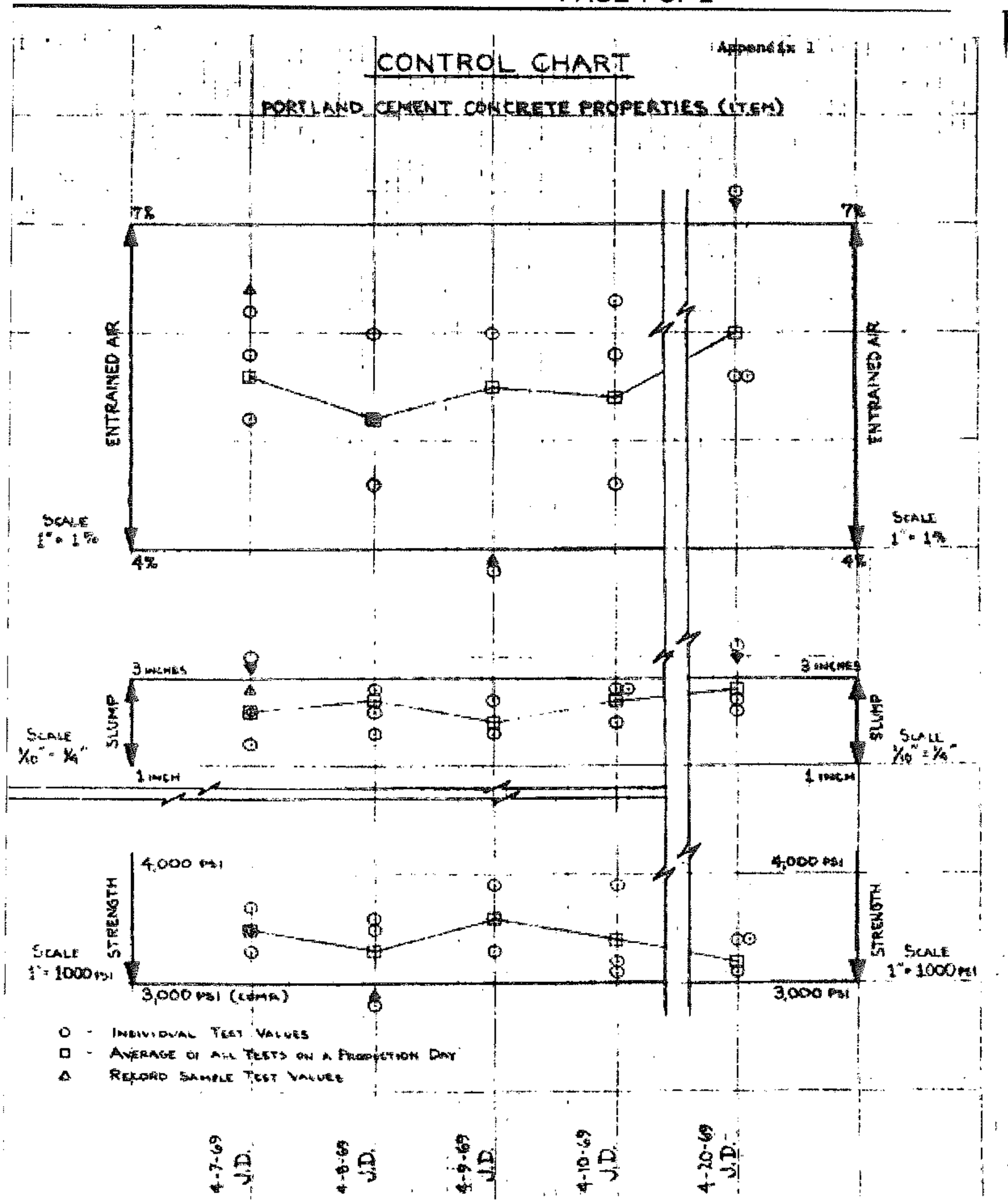
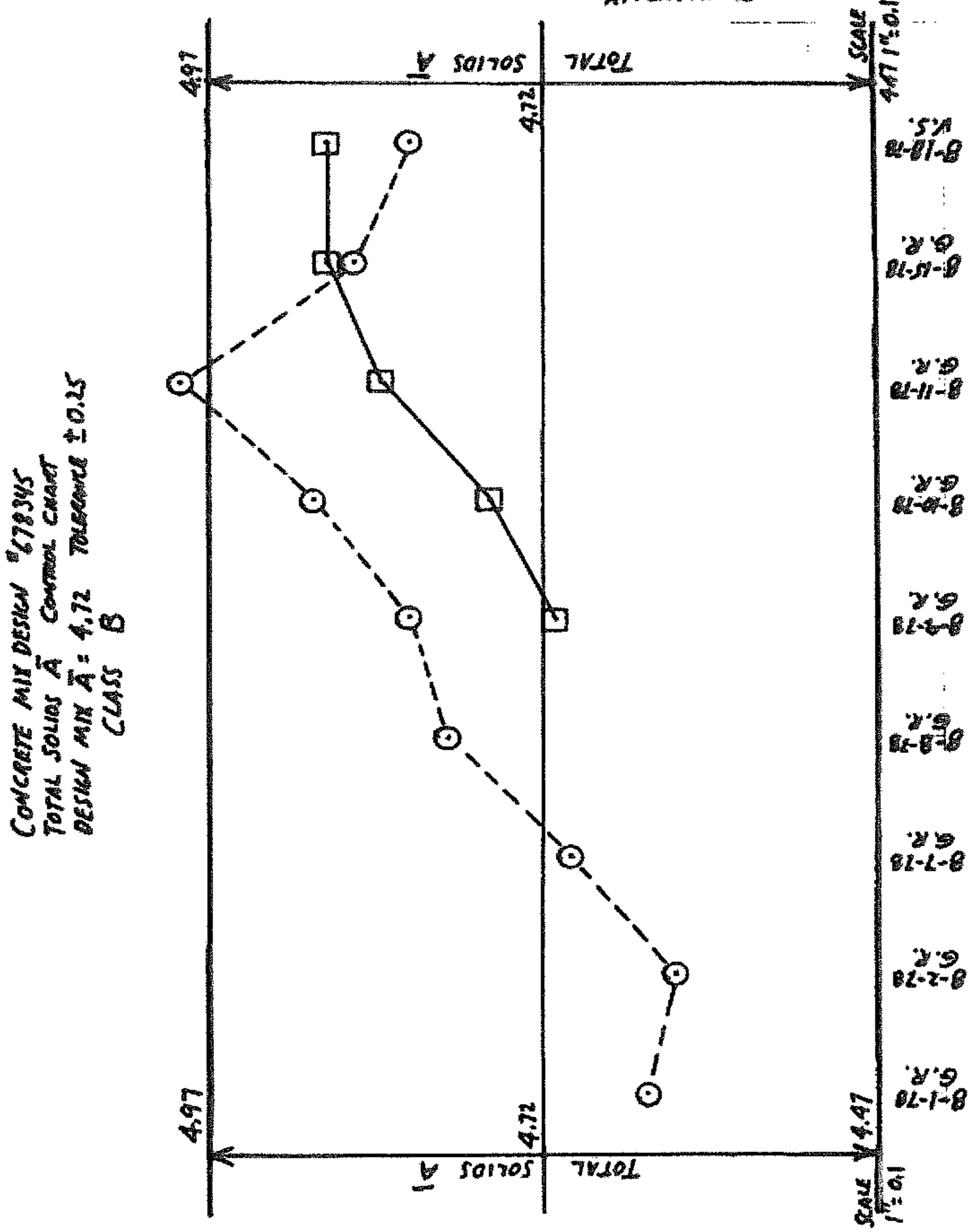
GLR:w

Attachments


Appendix 1
CONTROL CHART
PORTLAND CEMENT CONCRETE PROPERTIES (ITEM)
7%
ENTRAINED AIR
SCALE
1" = 1%
4%
3 INCHES
SLUMP
SCALE
1/10" = 1/4"
1 INCH
4,000 PSI
STRENGTH
SCALE
1" = 1000 PSI
3,000 PSI (CDMR)
3,000 PSI
O - INDIVIDUAL TEST VALUES
□ - AVERAGE OF ALL TESTS ON A PRODUCTION DAY
Δ RECORD SAMPLE TEST VALUES
4-7-69 J.D.
4-8-69 J.D.
4-9-69 J.D.
4-10-69 J.D.
4-20-69 J.D.

APPENDIX 2


CONCRETE MIX DESIGN #678345
TOTAL SOLIDS Ā CONTROL CHART
DESIGN MIX Ā = 4.72 TOLERANCE ±0.25
CLASS B
TOTAL SOLIDS Ā
4.97
4.72
4.47
SCALE 1" = 0.1
8-1-78 G.R.
8-2-78 G.R.
8-7-78 G.R.
8-8-78 G.R.
8-9-78 G.R.
8-10-78 G.R.
8-11-78 G.R.
8-15-78 G.R.
8-18-78 V.S.

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

CURING CONCRETE TEST SPECIMENS IN THE FIELD

1.0 PURPOSE

1.1 The purpose of this procedure is to modify the curing requirements for cylindrical and prismatic specimens that have been made in the field.

2.0 BACKGROUND

2.1 The Division's Standard Specifications (501.4 and 601.4) require that the making and curing of concrete test specimens in the field be done in accordance with AASHTO Designation T 23.

2.2 Section 9 of AASHTO Designation T 23 covers curing of the test specimens until time of test.

3.0 APPLICABLE DOCUMENT

3.1 AASHTO Designation T 23

4.0 PROCEDURE

4.1 Curing of cylindrical and prismatic specimens made in the field shall be in accordance with Section 9 of AASHTO Designation T 23 with modifications as follows.

4.1.1 Delete the section that covers initial curing (10.1.2 in T23-04) and substitute the following:

10.1.2 Initial Curing - Immediately after molding and finishing, the specimens shall be stored for a period of 24 ± 8 hours in a temperature range from 60 to 80°F (16 to 27°C), and in an environment preventing moisture loss from the specimens. For concrete mixtures with a specified strength of 6000 psi (40 MPa) or greater, the initial curing temperature shall be between 68 and 78°F (20 and 26°C). Various procedures are capable of being used during the initial curing period to maintain the specified moisture and temperature conditions. An appropriate procedure or combination of procedures shall be used (Note 6). Shield all specimens from direct sunlight and, if used, radiant heating devices. The storage temperature shall be controlled by the use of heating and cooling devices, as necessary. Record the temperature using a maximum-minimum thermometer. If cardboard molds are used, protect the outside surface of the molds from contact with wet burlap or other sources of water.

4.1.2 Delete the section that covers transportation of specimens to the laboratory (11.1 in T23-04) and substitute the following:

11.1 Prior to transporting, cure and protect specimens as required in Section 9. When standard curing is used, specimens shall be transported within 24 ± 8 hours after molding. When field curing is used, specimens shall not be transported to the laboratory until just prior to testing. During transporting, protect the specimens with suitable cushioning material to prevent damage from jarring. During cold weather, protect the specimens from freezing with suitable insulation material. Prevent moisture loss during transportation by wrapping the specimens in plastic, wet burlap, by surrounding them with wet sand or tight fitting plastic caps on plastic molds. Transportation time shall not exceed 4 hours.

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WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

USE OF THE MATURITY METHOD FOR THE ESTIMATION OF CONCRETE STRENGTH ON WVDOH PROJECTS

1. PURPOSE

1.1 To establish a procedure to estimate the compressive strength of concrete, used on West Virginia Division of Highways (WVDOH) projects, with the Maturity Method.

2. SCOPE

2.1 This procedure shall apply to all Contractors, Sub-contractors, Consultants, and WVDOH Personnel who test concrete on WVDOH projects.

2.2 This procedure may be used in place of compressive strength cylinders, for the determination of the compressive strength of concrete, when allowed by the WVDOH Specifications. The Maturity Method shall not be permitted as a substitute for 28-day acceptance cylinders.

3. REFERENCED DOCUMENTS

- ASTM C1074 – Standard Practice for Estimating Concrete Strength by the Maturity Method

4. PROCEDURE

4.1 The procedure outlined in the following sections shall be applied to each WVDOH approved concrete mix design for which the Maturity Method is desired to be used in place of concrete cylinders for the estimation of the concrete strength in the field. A separate strength-maturity relationship must be developed for each approved concrete mix design.

4.2 DEVELOPMENT OF STRENGTH-MATURITY RELATIONSHIP

4.2.1 Fabricate a minimum of fifteen concrete cylinders, in accordance with ASTM C192, from each WVDOH approved concrete mix for which it is desired to establish a strength-maturity relationship. The mixes used to cast these cylinders shall be batched as closely as possible to the anticipated target air content and slump values and chemical admixture dosage rate which will be used in the field.

4.2.2 Either 6-inch x 12-inch cylinders or 4-inch x 8-inch cylinders may be used to develop the strength-maturity relationship, but if 4-inch x 8-inch cylinders are going to be used, then 4-inch x 8-inch cylinders must be approved to be used, in accordance with MP 711.03.23, with the mix design for which the strength-maturity relationship is being developed.

4.2.3 Follow the procedure outlined in Section 8 of ASTM C1074-11, and establish a strength-maturity relationship and corresponding Strength-Maturity Curve. The maturity of the subject cylinders shall be recorded to the nearest degree-hour. The axes used to plot this Strength-Maturity Curve shall be Strength, expressed in pounds per square inch on the Y-axis, and Temperature-Time Factor, expressed in °C-hours on the X-axis.

4.2.4 When concrete mixes designed for rapid strength gain are used, the compression tests shall be conducted at ages approved by the Engineer based on the strength development characteristics of that mix. However, a minimum of five test ages shall be used.

4.2.5 Minor variations from the conditions encountered during establishment of the strength-maturity relationship may be encountered in the field during actual concrete placement. These conditions may include higher than anticipated air content, slightly higher slump/water content, etc. To account for this, and to build in a factor of safety, a second strength-maturity curve shall be constructed similar to the first curve (Strength-Maturity Curve), but using compressive strength results which are ten-percent lower than those obtained in Section 4.2.1. This curve, constructed ten-percent below the Strength-Maturity Curve, shall be referred to as the "Construction Maturity Curve".

4.3 APPLICATION OF STRENGTH-MATURITY RELATIONSHIP

4.3.1 The Construction Maturity Curve shall be the curve which may be used in the field at the Project, in place of compressive strength cylinders, to estimate the compressive strength of the concrete in question.

4.3.2 The strength-maturity relationship and Construction Maturity Curve shall not be permitted to be used in place of 28-day acceptance cylinders. The strength-maturity relationship and Construction Maturity Curve shall only be used for the purposes of opening structures to traffic (i.e. Section 501.4.4, Section 506, etc.) and for form removal and construction of superimposed elements (i.e. Section 601.8.7).

4.4 VALIDATION OF STRENGTH-MATURITY RELATIONSHIP

4.4.1 After ten days of production or after sufficient concrete has been placed, such that ten sets of compressive strength acceptance cylinders would be required, seven "Maturity

Validation Cylinders" shall be fabricated. One of these cylinders shall have a maturity sensor installed in it within ± 5/8" of the center of the cylinder. Three of these cylinders shall be tested at an age of three days and three of these cylinders shall be tested at an age of seven days. The average of each of these sets of three cylinders shall be the average compressive strength at that age.

4.4.2 The Maturity Validation Cylinders shall be the same size as the cylinders which were used to develop the original Strength-Maturity Curve.

4.4.3 If either of the average compressive strengths obtained in Section 4.4.1 fall at a point lower than the Construction Maturity Curve, additional maturity validations at three and seven days, as outlined in Section 4.4.1, shall be conducted on the next three concrete placements. The Contractor shall continue to conduct these maturity validations until three consecutive validations (consisting of both three and seven day results) are all at points above the Construction Maturity Curve.

4.4.4 If, after five maturity validations, the Contractor has not obtained three consecutive validations which are all at points above the Construction Maturity Curve, then a new strength-maturity curve shall be established, as outlined in Section 4.5.

4.5 ESTABLISHMENT OF NEW STRENGTH-MATURITY CURVE

4.5.1 The new average three-day strength shall be established by averaging the five three-day strength results from the five maturity validations. The new average seven-day strength shall be established by averaging the five seven-day strength results from the five maturity validations.

4.5.2 The percent by which the average three-day strength is below the Strength-Maturity Curve shall be calculated. The percent by which the average seven-day strength is below the Strength-Maturity Curve shall also be calculated. The greater of these percentages shall be the percent by which the Strength-Maturity Curve is lowered. A new Construction Maturity Curve shall then be established, as outlined in Section 4.2.5, at ten percent below the new Strength-Maturity Curve.

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WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

SAMPLING AND TESTING OF MATERIALS AT THE SOURCE

1.0 PURPOSE

1.1 To provide definitions and general guidelines of source sampling and testing to minimize nonspecification material arriving at the project site.

2.0 SCOPE

2.1 This procedure applies to materials sampled at the source (or some intermediate storage area) on a lot by lot basis.

3.0 DEFINITIONS

3.1 Presampling - The sampling operation that is completed while the material is at the source, or other intermediate storage area, prior to shipment to the project site. Presampled material cannot be used until authorization of approval is received from Materials Control, Soil and Testing Division.

3.2 Pretesting - The testing of presampled material. A pretested material is that which has been sampled, tested, and evaluated prior to shipment to the project site. Such material may be used upon arrival at the project site.

4.0 PROCEDURE

4.1 Sampling Frequency

4.1.1 Frequency of sampling shall be in accordance with applicable directives for specific items.

4.2 Sampling

4.2.1 All material will be sampled by an authorized representative of the Division. Sampling will be conducted in accordance with the applicable directives.

4.3 Identifying Presampled Material

4.3.1 When a specific quantity (lot) of material has been sampled, the material shall be set aside (isolated) and marked, sealed, tagged, or otherwise identified during storage as being presampled. The material shall be stored with reasonable assurance that it will not be contaminated, included, or mixed with other materials that have not been represented in the sampling plan.

4.3.2 Identifying records shall include the following (where applicable), and must accompany the sample to the laboratory:

a) Name of manufacturer
b) Date of manufacturer
c) Batch or lot identification
d) Quantity represented
e) Date sampled
f) Test required
g) Sampler
h) Project number
i) Any other information necessary to identify the material

4.4 Identifying Pretested Material

4.4.1 Packaged Material - When tests indicate packaged material has met the specification requirements they may be tagged, sealed, stamped, or otherwise identified by the state representative as having been pretested and approved.

4.4.2 Bulk or Miscellaneous Materials - When tests indicate bulk or miscellaneous materials have met specification requirements they may be stored in suitable enclosures until shipped. These enclosures may be tagged, sealed, stamped, or otherwise identified by the state's representative as having been pretested and approved. If appropriate, miscellaneous materials may be individually identified by tag, seal, or stamp as being pretested and approved. When closed conveyances are used to ship pretested materials, these conveyances may be tagged, sealed, stamped, or similarly treated to identify the contents as being pretested and approved for shipment to the project site.

5.0 DOCUMENTATION

5.1 Documentation of Samples - Samples must be documented setting forth all information necessary for proper identification of the materials in accordance with section 4.3.2.

5.2 Sample Document Distribution - Original documentation shall be transmitted with the sample to the testing laboratory. The sampler will retain a copy of this documentation.

5.3 Documentation of Test Results - The testing laboratory will perform all required tests and document the results on the appropriate form. A concluding statement on the form shall indicate that the material does or does not meet the requirements of the controlling specifications. This form shall also contain all applicable identifying information described in Section 4.3.2.

5.4 Testing Document Distribution

5.4.1 When testing is done by a Division approved laboratory, a copy of the test report will be furnished to Materials Control, Soil and Testing Division.

5.4.2 Test reports will be reviewed, assigned a laboratory number, and distributed by Materials Control, Soil and Testing Division as required.

5.5 Shipping Documentation - When test results indicate the material has met the specification requirements, authorization is given for shipment to the project site. The supplier shall prepare a shipping document and shall include as a minimum the following:

a) All information applicable in Section 4.3.2
   (1) Information applicable for the shipment of aggregate, asphalt, and concrete include all items except c, e, f, and g of the above referenced section.
   (2) Information applicable to shipment of paint include all items except e, g, and h of the above referenced section.
b) Date of shipment
c) The laboratory number assigned to the approval document

When the material is from stock identified by a Master Laboratory Number, a copy of the shipping document will be transmitted to the Finalization Section of the Contract Administration Division, A copy of the shipping document will always accompany the shipment and be included in the project file.

5.6 Final Acceptance of Pretested Material - Tests completed on materials at the source may be used by the Division for acceptance. However, the Division reserves the right to resample and retest the materials at the source or after the materials have arrived at the project.

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WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

AGGREGATE SAMPLING PROCEDURES

1.0 PURPOSE

1.1 To provide a uniform procedure for obtaining aggregate samples.

2.0 SCOPE

2.1 This procedure shall apply to the following:

(a) Process Control sampling by the Contractor.

(b) Acceptance Sampling by the Division.

(c) Independent Assurance Sampling by the Division.

(d) Record Sampling by the Division.

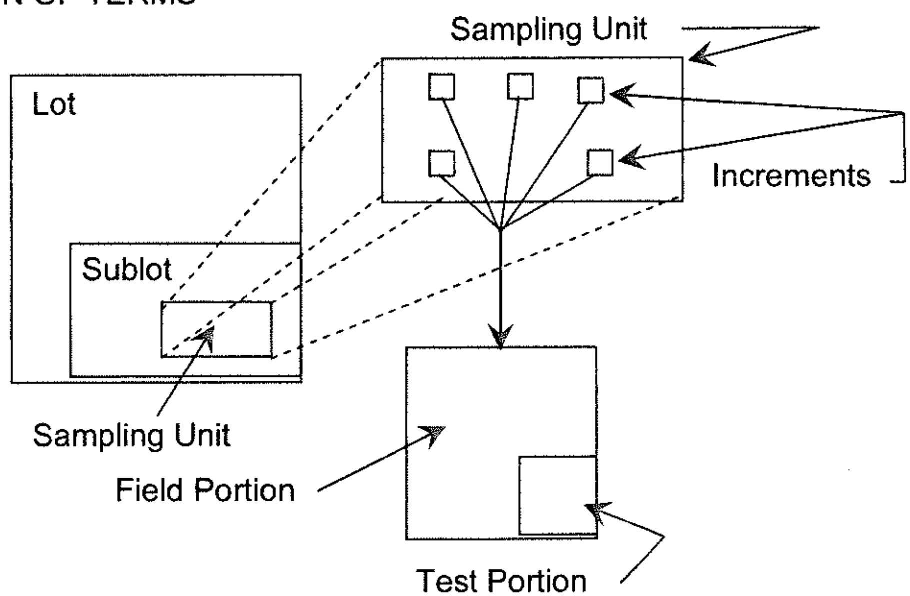
3.0 GENERAL

3.1 Taking a good sample is just as important as conducting a good test. The sampler must use every precaution to obtain samples that will show the true nature and condition of the material they represent.

3.2 Most aggregates are mixtures of various particle sizes, which tend to separate, or segregate, during transporting or stockpiling. For this reason aggregate samples should be obtained at the last practical point before the material is incorporated into the finished product or before compaction.

3.3 Frequency of sampling will be in accordance with the applicable directives for the type sample being procured.

4.0 DEFINITION OF TERMS



4.1 Lot: The quantity of material represented by an average test value. not to exceed five individual test values, calculated in accordance with MP 300.00.51

4.2 Sublot: The quantity of material represented by a single test value. In the case where only one sample is needed for the total plan quantity, the sublot may be considered the Lot.

4.3 Sampling Unit: The quantity of material within the sublot from which increments are obtained to be combined into a field sample.

4.4 Increment: The portion of material removed from the sampling unit to be combined into a field sample.

4.5 Field Sample: A composite of increments.

4.6 Test Portion: The material split from the field sample to be used in performing a specific test.

4.7 Random Location: A location whose position depends entirely on chance. In other words, one location has as good a chance being selected as any other.

5.0 CONTRACTOR RESPONSIBILITY

5.1 The Contractor shall provide suitable equipment needed for proper inspection and sampling, including required access and any special equipment necessary to comply with the appropriate sampling techniques outlined herein. (See Section 105.5 (5th Paragraph) and Section 105.11 (1st Paragraph) of the 2000 Standard Specifications for Roads and Bridges.)

6.0 SAMPLING PROCEDURES

6.1 There are four general areas from which aggregate samples are usually obtained. These include (1) Sampling from the roadway after the aggregate has been placed, but prior to compaction, (2) Sampling from a conveyor belt, (3) Sampling from a flowing stream of aggregate, and (4) Sampling from stockpiles.

6.1.1 Sampling from the roadway (e.g., bases and subbases). The first step in obtaining a roadway sample is to locate the sublot. This is usually the quantity of material that will be represented by the one sample and is defined as a section of roadway of given width and length. The next step is to randomly locate a sampling unit within the sublot. A sampling unit is defined as an area having dimensions of approximately12 feet by 12 feet, or an area of approximately 144 feet^2 in locations having any dimension less than 12 feet. Locating the sampling unit is accomplished by use of random numbers contained in Attachment I. Any pair of numbers (decimals) may be used to locate a sampling unit within the sublot. To locate the sampling unit in a sublot defined by area, the length of the area, in feet, is multiplied by one decimal of the pair, and width is multiplied by the other decimal. The resulting distances are to be measured from one end and one side of the area. For example, a sublot of material consists of base course aggregate 26 feet wide from Station 956+00 to 965+00. The total length in feet is thus 96500 minus 95600, or 900 feet. A pencil tossed on Attachment I points to the pair of decimals 0.115 and 0.447. To locate the sampling unit, the first decimal is multiplied by the length of the sublot, and the companion decimal is multiplied by the width.

The length value will be measured from Station 956+00 and the width value from the left-hand edge of the base. Thus, 900 times 0.115 equals 104, and 26 times 0.447 equals 12, so the sampling unit would be located at Station 956+00 plus 1+04, or 957+04 at 12 feet from the left edge. This point could define the center or any corner of the sampling unit. If we use the center, a 12 foot by 12 foot sampling unit would fall between Stations 956+98 and 957+I0 with longitudinal boundaries 6 feet and 18 feet from the left edge of the base. Five approximately equal increments are then located within the sampling unit. This is also best accomplished by means of the random numbers in Attachment 1. Procedures to follow are essentially the same as those set forth for locating the sample unit. The five increments are taken from the sampling unit and combined to form a field sample whose weight equals or exceeds the minimum recommended in Table 1. All increments shall be taken from the roadway for the full depth of the material being sampled, care being taken to exclude any foreign material which may have been incorporated during the normal construction process. The specific areas from which each increment is to be removed shall be clearly marked; a metal template placed over the area is a definite aid in securing approximately equal increment weights.

6.1.2 Sampling from a Conveyor Belt. The first step in obtaining a sample from the conveyor belt is to define the sublot. This is generally defined as a unit of time, i.e., a half-day or a day's production. The next step is to randomly locate a sampling unit within the sublot. A sampling unit in this case is generally considered to be the material contained within the length of the conveyor. Locating the sampling unit is accomplished by use of the random numbers contained in Attachment I. Any number may be used to locate a sampling unit within the sublot. To locate the sampling unit in a sublot defined by time, the length of time, usually in minutes, is multiplied by the random decimal obtained from Attachment I. For example, a sublot of material consists of concrete aggregate used in a half-day's production estimated to be between 8:00 a.m. and 12:00 noon. A pencil tossed on Attachment I points to decimal 0.279. Thus, the sampling unit would be located somewhere within the four hour period (8:00 a.m. to 12:00 noon). Four (hours) times 60 (minutes per hour) times 0.279 equals 67 minutes. The sampling unit would be located 67 minutes after the 8:00 a.m. startup; or at 9:07 a.m. (or as soon thereafter as practical). Five randomly located, approximately equal increments are obtained from the sampling unit and

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combined to form a field sample whose weight equals or exceeds the minimum recommended in Table 1. The location of the five increments is determined by multiplying the length of the belt by five random numbers. The conveyor belt is stopped while the increments are being obtained. Two templates, conforming to the shape of the belt and spaced such that the material contained between them will yield an increment of the required size, are inserted into the aggregate stream on the belt. All material between the templates is carefully scooped into a suitable container, including all fines on the belt collected with a brush and dustpan.

6.1.3 Sampling from a Flowing Aggregate Stream (bin or belt discharge). Definition of the sublot and location of the sampling unit is generally identical with sampling from a conveyor belt, with the exception that the sampling unit in this case is defined as that material which will flow during a five minute period. Once the sampling unit is located, five approximately equal increments, randomly spaced, are obtained and combined to form a field sample whose weight equals or exceeds the minimum recommended in Table 1. Each increment is taken from the entire cross-section of the material as it is being discharged. It is usually necessary to have a special device constructed for use at each particular plant. This device will consist of a pan of sufficient size to intercept the entire cross-section of the discharge stream and hold the required quantity of material. A set of rails may be necessary to support the pan as it is passed under the discharge stream. If the sampling pan overflows, it should be struck level so that only material that is within the pan is retained.

6.1.4 Sampling from a Stockpile. If possible, stockpile sampling should be avoided when sampling to determine the gradation of an aggregate. However, circumstances sometimes make it necessary, and when this occurs a sampling plan and the number of samples to be taken must be considered for each specific case. Stockpiled aggregates tend to segregate with the coarser particles rolling to the outside base of the pile, which makes gradation representation difficult. Because of this, every effort should be made to enlist the services of power equipment (such as a front-end loader) to develop a separate small sampling pile composed of material taken from various levels and depths in the main pile. Increments from this pile may be combined, thoroughly mixed, and reduced by quartering and/or sample splitter to obtain the field sample. Methods for quartering and splitting samples are given in AASHTO T248. If power equipment is not available, hand sampling may be employed to obtain at least three increments per sample: One increment taken from the top one third of the pile, one from the middle and one from the bottom third. When hand sampling, the outer layer of the pile should be removed (scraped away with the shovel) at the point prior to sampling.

7.0 WEIGHTS REQUIRED

7.1 Field Sample Weights

Field sample weights as listed in Table I are minimum values. Actual weights required must be predicated on the type and number of tests to which the material is to be subjected. Generally speaking, the amounts specified in Table I will provide adequate material for routine gradation and quality analysis.

7.2 Test Portion Weight

The weight of the test portion to be obtained from the field sample for a particular test will be defined in the Standard Procedures of the test involved. Reduction of the field sample into test portions is done with a sample splitter. The weight of test portion recommended for gradation testing is given in Table II.

8.0 TRANSPORTING SAMPLES

8.1 Testing at Site of Sampling

Samples taken for testing In the field may be placed in any suitable clean container of appropriate size which is secure enough to prevent loss of material when transporting the sample to the testing location.

8.2 Samples to be Shipped from Site of Sampling

Samples to be shipped should be placed in standard sampling sacks. If the sample contains an appreciable quantity of fine material, a plastic liner should be put in the sack to prevent loss of the fines. Each sack must be securely tied to prevent loss of material in transit. It is also essential that sample identification be maintained from the field to the testing site. Each sack must have appropriate indelible identification attached and enclosed so that field reporting, laboratory logging, and test reporting may be facilitated.

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Attachments

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TABLE I

WEIGHT OF SAMPLES

NOMINAL MAXIMUM SIZE OF PARTICLES*	MINIMUM WEIGHT OF FIELD SAMPLES	
Sieve Size	Kilo	lb
No. 8	10	25
No. 4	10	25
3/8 in.	10	25
1/2 in.	15	35
3/4 in.	25	55
1 in.	50	110
1 1/2 in.	75	165
2 in.	100	220
2 1/2 in.	125	275
3 in.	150	330
3 1/2 in.	175	385

*The nominal maximum size of particles is defined as the largest sieve size listed in the applicable specifications upon which any material is permitted to be retained. Exception: If the specification tolerances are such that no sieve listed has a range of X-100 percent passing, then the next smallest standard sieve, as listed in Table I, and below that sieve which 100 percent must past will be considered the nominal maximum size.

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TABLE II

TEST PORTION FOR GRADATION

NOMINAL MAXIMUM SIZE OF PARTICLES	MINIMUM WEIGHT OF TEST PORTION	
Sieve Size	Kilo	lb
No. 8	0.1	0.3
No. 4	0.5	1.0
3/8 in.	1.0	2.0
1/2 in.	2.0	4.0
3/4 in.	5.0	11.0
1 in.	10.0	22.0
1 1/2 in.	15.0	33.0
2 in.	20.0	44.0
2 1/2 in.	35.0	77.0
3 in.	60.0	130.0
3 1/2 in.	100.0	220.0

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ATTACHMENT I

RANDOM NUMBERS

.858	.082	.886	.125	.263	.176	.551	.711	.355	.698
.576	.417	.242	.316	.960	.879	.444	.323	.331	.179
.587	.288	.835	.636	.596	.174	.866	.685	.066	.170
.068	.391	.139	.002	.159	.423	.629	.631	.979	.399
.140	.324	.215	.358	.663	.193	.215	.667	.627	.595
.574	.601	.623	.855	.339	.486	.065	.627	.458	.137
.966	.589	.751	.308	.025	.836	.200	.055	.510	.656
.608	.910	.944	.281	.539	.371	.217	.882	.324	.284
.215	.355	.645	.450	.719	.057	.287	.146	.135	.903
.761	.883	.711	.388	.928	.654	.815	.570	.539	.600
.869	.222	.115	.447	.658	.989	.921	.924	.560	.447
.562	.036	.302	.673	.911	.512	.972	.576	.838	.014
.481	.791	.454	.731	.770	.500	.980	.183	.385	.012
.599	.966	.356	.183	.797	.503	.180	.657	.077	.165
.464	.747	.299	.530	.675	.646	.385	.109	.780	.699
.675	.654	.221	.777	.172	.738	.324	.669	.079	.587
.269	.707	.372	.486	.340	.680	.928	.397	.337	.564
.338	.917	.942	.985	.838	.805	.278	.898	.906	.939
.130	.575	.195	.887	.142	.488	.316	.935	.403	.629
.011	.283	.762	.988	.102	.068	.902	.850	.569	.977
.683	.441	.572	.486	.732	.721	.275	.023	.088	.402
.493	.155	.530	.125	.841	.171	.794	.850	.797	.367
.059	.502	.963	.055	.128	.655	.043	.293	.792	.739
.996	.729	.370	.139	.306	.858	.183	.464	.457	.863
.240	.972	.495	.696	.350	.642	.188	.135	.470	.765

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

CERTIFICATION OF BATCH SCALES AND CALIBRATION OF STANDARD 50 POUND TEST WEIGHTS

1.0 PURPOSE

1.1 To provide instructions and establish frequency for having batch scales checked and approved.

1.2 To provide procedural instructions for having standard 50 pound test weights checked and approved.

2.0 SCOPE

2.1 This procedure will apply to all batch plants furnishing Portland cement concrete or bituminous concrete to State Highway projects.

3.0 INSTRUCTIONS

3.1 Batch scales shall be checked and approved by the Division of Labor at least once a year.

3.2 Standard, 50 pound, test weights shall be certified as correct by the Division of Labor at the time and location designated by their directives.

3.3 Certification of standard test weights by the West Virginia Division of Labor will be evidenced by the letters WV and a two digit number stamped on the lead plug in each of the standard weights, the two digits representing the year in which certification is made.

3.4 Standard test weights should be treated in the following manner prior to delivery to the calibration station.

3.4.1 Wire brush to remove all dirt and rust, and paint with a light coat of aluminum paint.

4.0 FACILITIES LOCATED OUTSIDE OF WEST VIRGINIA

4.1 The Division may, at its option, accept inspection and sealing by out of state agencies.

4.2 The frequency of such inspection shall conform to West Virginia's Division of Labor requirements.

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RDG:b

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

PORTLAND CEMENT MILL CERTIFICATION

1.0 PURPOSE

1.1 To provide the Division's acceptance procedures for Portland Cement.

2.0 SCOPE

2.1 This procedure shall apply to all Portland Cement production mills which furnish cement to Division projects except that the Division may elect to use other control procedures when special conditions dictate the need for more stringent control.

3.0 APPLICABLE SPECIFICATIONS

3.1 All items under this procedure shall meet the requirements of Section 701 of the WVDOH Standard Specifications for Roads and Bridges. This section specifically includes ASTM Specification C-150. In addition, samples will be obtained in accordance with ASTM C-183.

4.0 PROCEDURE

Cement mills which produce cement for use in Division projects shall be identified as Certified or Non-Certified, as outlined below.

4.1 CERTIFIED

To be considered for certification, the manufacturer shall do the following:

4.1.1 Submit a certified statement to Materials Control, Soils and Testing Division that all cement shipped to Division projects will conform to the specification requirements.

The certified statement shall be signed by a representative of the manufacturer having legal authority to bind the company.

4.1.2 Maintain records of production control tests for a period of at least five years and make them available to the Division upon request.

4.1.3 Have mill laboratory facilities periodically inspected by the Bureau of Standards Cement and Concrete Reference Laboratory (CCRL). A copy of the CCRL report on the mill laboratory inspection shall be provided to the Division, accompanied by documentation of resolution of any discrepancies noted in the CCLR report.

4.1.4 Submit to the Materials Division test data developed on the type(s) of cement to be certified. This data must consist of test results developed from each day's production over the most recent fifty production days. The required tests are for all the standard chemical and physical requirements listed in ASTM C-150. Each complete battery of tests shall represent not more than twenty-four hours of continuous production per finish mill.

4.1.5 The quality history of a cement plant seeking certification will be determined using the data submitted by the manufacturer as specified in 4.1.4. Statistical limits, as defined in ASTM C-183, will be developed from this data from this data. When an acceptable quality history has been determined, the Division will compare test data developed on production grab samples taken by Division representatives, to the statistical limits established by the mill's production data.

4.1.6 When a cement mill has met the above criteria and has been designated by the Division as Certified, the manufacturer will be required to submit test data on a monthly basis in the same manner as described in 4.1.4.

4.1.7 Division representatives will take paired samples from a certified plant's production at a frequency dependent upon the variability of test data. The frequency will generally be such that the sampling is accomplished at least once a quarter.

4.1.7.1 The paired samples will be obtained, tested, and evaluated in accordance with applicable ASTM procedures.

4.1.7.2 Two consecutive pairs of test values failing to meet the statistical control criteria may be considered cause to remove the mill from the certified group.

4.1.7.3 If any individual sample fails to meet the requirements of the applicable ASTM Specification, the mill may be removed from the certified group.

4.1.7.4 If a certification is removed, it may be reinstated at the discretion of the Division when sufficient sampling and testing has been conducted to insure statistical control.

4.1.8 When all requirements for certification have been met, the manufacturer may ship cement of the type certified to Division projects. Records of quantities of cement shipped to West Virginia projects must be maintained by the manufacturer for a minimum of three years and made available to the Division upon request.

4.1.9 The manufacturer and the Division's District Materials offices will be notified of all changes in the status of a mill's certification.

4.1.10 Once each quarter, or anytime the list is updated , the Materials Division will provide the District with a list of all currently certified cement mills.

4.2 Non-Certified

A cement mill defined as non-certified may supply cement to the Division projects from approved LOTs.

4.2.1 The Division will sample, test, approve, and seal LOTs of cement for use in Division projects. Samples will be obtained in accordance with ASTM C-183 except that one grab sample shall be secured for each 400 tons in the sampling of bulk storage at points of discharge, while the cement is flowing through the openings. All of the applicable chemical and physical tests noted in ASTM C-150 will be conducted by the Division laboratories.

4.2.1.1 Any individual sample failing to meet all of the applicable ASTM requirements will result in rejection of the entire LOT of cement.

4.2.2 When a LOT of cement has been sampled, tested, and found to meet all specification requirements, the Division will notify the manufacturer of approval and a WVDOH approval number will be assigned to the LOT.

4.2.3 A manufacturer may make shipments from approved LOTs upon notification of Division approval. When such shipments are made the manufacturer shall provide documentation as follows:

a) Project to which material is shipped (if available)
b) Silo number from which material drawn
c) Location of shipping origin
d) Contractor (i.e. consignee)
e) WVDOH approval number assigned to silo
f) Identification of carrier
g) Quantity of material in shipment
h) Type of material

4.2.3.1 This documentation may be provided in the form of bills of lading and shall have the following distribution:

a) 1 copy sent to Materials Control, Soils and Testing Division
b) 1 copy sent to accompany shipment and to be left at the destination to become the property of the Division

4.2.3.2 Records of quantities of cement shipped to West Virginia projects must be maintained by the manufacturer for a minimum of three years and made available to the Division upon request.

4.2.3.3 A balance sheet shall be maintained by the manufacturer for each LOT of cement approved for shipment to West Virginia projects. This balance sheet shall provide the following information:

a) The silo number
b) The Division approval number assigned to the silo
c) The test quantity

d) Separate entries for each shipment made from the silo showing bill of lading number and quantity.

e) The balance left in the test quantity after each shipment

4.2.3.4 The manufacturer may not ship material in excess of the test quantity plus five percent (5%).

Gary L. Robson, Director
Materials Control, Soils
and Testing Division

GLR: d

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

DETERMINING FREE MOISTURE IN FINE AGGREGATE USING A "SPEEDY MOISTURE TESTER"

1.0 PURPOSE

1.1 To establish a standard method of test for determining free moisture (moisture above saturated surface dry) in fine aggregate using a "Speedy Moisture Tester".

2.0 SCOPE

2.1 This method of test is applicable to free moisture determination when using either the 20 gram or 26 gram "Speedy Moisture Tester".

3.0 GENERAL

3.1 Concrete design computations are based on aggregates which are in the SSD condition. Therefore, in this procedure the expression of free moisture is based on the SSD weight of the material.

3.2 The dial reading on the "Speedy Moisture Tester" is the percent total moisture based on the wet weight of the sample. The average absorption for limestone and silica sand is approximately 1.5 percent based on the dry weight of the material. Conversion tables calculated from this average are provided on Attachment I to yield the percent free moisture in the sample from the dial reading of the "Tester".

3.3 If it is known that the absorption should not be based on the 1.5 percent average (when the absorption is less than 1 or greater than 2) then the method for calculating the free moisture from the dial reading is given in Section 6.0.

4.0 EQUIPMENT

4.1 All equipment is contained in a "Speedy Moisture Tester" kit as obtained from a laboratory equipment supplier and consists of the following:

a) 20 gram or 26 gram tester - body and cap
b) Simple beam type scale
c) Reagent measurer
d) Reagent - calcium carbide
e) Cleaning cloth and brush

5.0 PROCEDURE

a) Place the scale in operating position and clean the pan.

b) Ensure the inside of the body of the tester is free from all foreign matter.

c) Add three measures of the reagent to the body of the tester.

d) Accurately weigh the sample (20 g or 26 g) on the scale. The accuracy of the scale should be established periodically.

e) Place the weighed sample in the cap of the tester.

f) With the pressure vessel in an approximately horizontal position, insert the cap in the pressure vessel and seal the unit by tightening the clamp, taking care that no reagent comes in contact with the aggregate until a complete seal is achieved.

g) Place the tester in a vertical position (cap end up) so that the aggregate will fall into the pressure vessel.

h) Shake the tester vigorously from end to end. At the first movement of the dial needle, turn the dial end up.

i) When the needle stops moving, read the dial while holding the instrument in a horizontal position at eye level. Read to the nearest 0.1 percent.

j) The percent free moisture is determined by entering the conversion chart (Attachment I) with the dial reading and obtaining the corresponding value of free moisture in the opposite column, or by substituting the dial reading into the equation shown in Section 6.0 - whichever the case may be.

6.0 SAMPLE CALCULATION

6.1 The following method for determining free moisture should be used when the absorption capacity of the aggregate is known to be outside the range of 1 percent to 2 percent (average 1.5 percent) of the aggregate dry weight (see Section 3.3).

Symbols		Given
W_D	= Dry Weight	AB = 3.0%
W_{SSD}	= Saturated Surface Dry Weight	DR = 10.0
W_w	= Wet Weight (Sample Weight)	*W_W = 20.0 or 26.0
DR	= Dial Reading	
AB	= Absorption	*Dependent upon size tester used
FM	= Free Moisture	

1. Determine the sample dry weight:

$$W_D = W_W - \frac{(W_W)\,DR}{100}$$

Substituting:

$$W_D = 26 - \frac{26\ (10)}{100}$$

$$W_D = 26 - 2.6$$

$$W_D = 23.4 \text{ g (dry weight)}$$

2. Determine from the dry weight the SSD weight:

$$W_{SSD} = W_D + \frac{W_D\,(AB)}{100}$$

Substituting:

$$W_{SSD} = 23.4 + \frac{23.4\,(3.0)}{100}$$

$$W_{SSD} = 23.4 + 0.702$$

$$W_{SSD} = 24.1 \text{ g (SSD weight)}$$

3. Determine from the SSD weight the percent free moisture:

$$\%FM = W_{SSD} - \frac{(W_{SSD})\,100}{W_{SSD}}$$

Substituting:

$$\%FM = \frac{(26 - 24.1)\,100}{24.1}$$

$$\%FM = \frac{190}{24.1}$$

$$\%FM = 7.9 \text{ (percent free moisture)}$$

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Attachment

SPEEDY MOISTURE TESTER CONVERSION CHART

SPEEDY DIAL READING WET BASIS	FREE MOISTURE SATURATED-SURFACE DRY BASIS	SPEEDY DIAL READING WET BASIS	FREE MOISTURE SATURATED-SURFACE DRY BASIS
1.0%	----	17.0%	18.7%
1.5%	----	17.5%	19.4%
2.0%	0.5%	18.0%	20.1%
2.5%	1.0%	18.5%	20.8%
3.0%	1.6%	19.0%	21.6%
3.5%	2.1%	19.5%	22.4%
4.0%	2.6%	20.0%	23.1%
4.5%	3.2%	20.5%	23.9%
5.0%	3.7%	21.0%	24.7%
5.5%	4.2%	21.5%	25.5%
6.0%	4.8%	22.0%	26.3%
6.5%	5.4%	22.5%	27.1%
7.0%	5.9%	23.0%	27.9%
7.5%	6.5%	23.5%	28.8%
8.0%	7.1%	24.0%	29.6%
8.5%	7.7%	24.5%	30.4%
9.0%	8.3%	25.0%	31.3%
9.5%	8.9%	25.5%	32.2%
10.0%	9.5%	26.0%	33.1%
10.5%	10.1%	26.5%	34.0%
11.0%	10.7%	27.0%	34.9%
11.5%	11.4%	27.5%	35.8%
12.0%	12.0%	28.0%	36.8%
12.5%	12.6%	28.5%	37.8%
13.0%	13.2%	29.0%	38.7%
13.5%	13.9%	29.5%	39.7%
14.0%	14.6%	30.0%	40.7%
14.5%	15.2%	30.5%	41.8%
15.0%	15.9%	31.0%	42.8%
15.5%	16.6%	31.5%	43.8%
16.0%	17.3%	32.0%	44.9%
16.5%	18.0%	32.5%	46.0%
----	---	33.0%	47.0%

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

GUIDE FOR APPROVAL OF POZZOLANIC ADDITIVES

1.0 PURPOSE

1.1 To set forth the Division's approval procedures for pozzolanic additives used in Portland cement concrete.

2.0 SCOPE

2.1 This procedure will apply to all pozzolanic additives used in Portland cement concrete that is used on West Virginia Division of Highways projects.

3.0 INITIAL APPROVAL

3.1 In order for a pozzolanic additive to be initially approved for use, the producer of the additive shall first submit a certified statement to the Materials Control, Soils and Testing (MCS&T) Division that all pozzolanic additives shipped to Division projects will conform to the applicable specification requirements. The certified statement shall be signed by a representative of the producer having legal authority to bind the company.

3.2 The producer shall also submit, to MCS&T Division, quality control test data on the pozzolanic additive to be certified. This data shall consist of test results developed from production samples during the last six months. These test results shall include results of all tests that are required by the specifications.

3.3 After the Producer has completed Sections 3.1 and 3.2, and if all test data submitted in Section 3.2 meets the applicable specification requirements, a representative of MCS&T Division shall obtain a sample of the pozzolanic additive from the source of production. The MCS&T Division shall test this sample, and if it meets specification requirements, a representative of the MCS&T Division shall obtain a second sample of the pozzolanic additive from the source of production or distribution (i.e. terminal). The MCS&T Division shall then test this second sample.

3.3.1 If either of the two samples obtained in Section 3.3 do not meet specification requirements, the pozzolanic additive will not be approved. If, at this time, the producer still seeks Division approval of the subject additive, a minimum of ninety calendar days (from the date that the non-conforming sample was obtained) must elapse before the approval process may begin again (starting with Section 3.1).

3.4 If the second sample obtained in Section 3.3 also meets specification requirements, the pozzolanic additive will be placed on the Division's approved list and the producer may begin to supply the subject material for use on Division projects.

4.0 APPROVED LIST

4.1 Once each quarter, or any time the list is updated, the MCS&T Division shall provide a list of all currently approved pozzolanic additives.

4.2 The producer and the District Materials Sections will be notified of any changes in the approved status of a pozzolanic additive.

4.3 No pozzolanic additive may be used in Portland cement concrete that is supplied to West Virginia Division of Highways projects unless it is on the Division's approved list of pozzolanic additives.

5.0 MAINTAINING APPROVED STATUS

5.1 In order to maintain approved status of the subject additive, the producer shall submit test data on a monthly basis in the same manner as described in Section 3.2.

5.2 Also, Division representatives from each District Materials Section shall obtain samples of the subject additive at every point of use (i.e. ready-mix plants, etc.) that is located within their District. A minimum of one sample shall be obtained from each particular location every three months. Within one week of obtaining these samples, the District personnel shall forward them to the MCS&T Division, where they shall be tested.

5.2.1 If any of the samples, obtained by District Personnel as outlined in Section 5.2, fail to meet the specification requirements, personnel from the MCS&T Division shall immediately obtain a sample of the subject material at the source of production or distribution (i.e. terminal). The MCS&T Division shall then test this sample.

5.2.2 If the sample obtained in Section 5.2.1 meets specification requirements, personnel from the MCS&T Division shall obtain a second sample at the source of production or distribution (i.e. terminal). If this second sample meets specification requirements, no further action is required, and the subject source may remain on the Division's approved list.

5.2.3 If either of the samples obtained in Sections 5.2.1 or 5.2.2 do not meet specification requirements, the subject material shall be removed from the Division's approved list.

5.2.4 If, within a twelve month period, two or more samples obtained as outlined in Section 5.2 (of the same material from the same approved source) fail to meet specification requirements, personnel from the MCS&T Division shall conduct an investigation into the possible reasons for the non-specification material. If the outcome of this investigation indicates a problem with material from the subject approved source, removal of that source from the approved list shall be permitted.

5.2.5 If a pozzolanic additive is removed from the approved list, it may be reinstated at the discretion of the Division when sufficient sampling and testing (at the source of production or distribution) has been conducted to ensure that material being produced is once again within the limits of the specifications.

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WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

MIX DESIGN FOR PORTLAND CEMENT CONCRETE

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1. PURPOSE

1.1 To establish a procedure for testing the physical properties of a proposed mix design.

1.2 To establish criteria for evaluating the test data to arrive at acceptable batch proportions for an approved mix design.

2. SCOPE

2.1 This procedure shall apply to the design of all portland cement concrete which is required by the specifications to be batched in accordance with an approved mix design with the exception of concrete specified in Section 603.

3. TEST PROCEDURE

3.1 The mix design shall be performed in accordance with the applicable requirements of ASTM C 192 by a Division Approved Laboratory. To obtain Division approval, a laboratory must demonstrate that they are equipped, staffed, and managed so as to be able to batch and test portland cement concrete in accordance with applicable ASTM Methods of Test. The most expeditious means of demonstrating such ability is by submission of a copy of the laboratory's latest report of concrete and aggregate inspection by the Cement and Concrete Reference Laboratory, National Bureau of Standards, together with a letter detailing the actions taken to correct any deficiencies noted therein. A listing of approved laboratories is available on the WVDOT internet site.

3.2 The following information for each of the materials listed below that are to be used in the proposed mix design shall be listed in Attachment 1.

3.2.1	Cement:	Type, Materials Code, Sitemanager Materials Code. Source and Location. Source Code, Producer/Supplier Code, Specific Gravity
	Pozzolan:	Type, Materials Code, Sitemanager Materials Code, Source and Location, Source Code, Producer/Supplier Code, Specific Gravity
	Chemical Admixtures:	Type, Materials Code, Sitemanager Materials Code, Source and Location, Source Code, Producer/Supplier Code
	Coarse Aggregate:	Type, Materials Code, Sitemanager Materials Code, Size, Source and Location, Source Code, Producer/Supplier Code, Specific Gravity, Absorption, A-Bar, Unit Weight
	Fine Aggregate:	Type, Materials Code, Sitemanager Materials Code, Source and Location, Source Code, Producer/Supplier Code, Specific Gravity. Absorption, A-Bar, Fineness Modulus

The mass and volume of each material that is to be used in each batch shall be listed in Attachment 2.

3.2.2 The aggregate correction factor, as defined in AASHTO T 152, shall be listed in Attachment 3.

3.2.3 The completed WVDOH form T301E, A-Bar calculation worksheet, used to establish the target A-Bar, shall be included in the mix design submittal package.

3.2.4 Information (i.e. raw data) pertaining to the compressive strength tests shall be included in the mix design submittal package. This raw data shall include the specimen test age, date tested, cylinder ID, average cylinder diameter, maximum load applied to the cylinder, type of fracture, and compressive strength of the cylinder.

3.3 All classes of the concrete (except Class H and concrete for specialized overlays) for the proposed mix design shall be batched in at least four separate batches. Two of the batches shall be proportioned to produce a mix having a minimum cement factor, and two of the batches shall be proportioned to produce a mix having a minimum cement factor equal to the specified minimum cement factor plus one bag of cement [94 lb (42.6 kg)].

3.3.1 Class H concrete and concrete for specialized overlays, as set forth in Section 679 of the specifications, for the proposed mix design shall be batched in at least two separate batches.

The batches for Class H concrete shall be produced at the cement factor for Class H concrete that is required in the specifications. Two rapid chloride permeability tests, in accordance with AASHTO T 277, specified in Section 601.3 shall be performed, at the same test age, on each of these batches, and the same method of curing shall be used for all of the test specimens.

The batches for specialized concrete overlays shall be produced at or above the minimum cement factor specified in Section 679.2.2.1 or 679.2.2.2. Two rapid chloride permeability tests specified in Section 679.2.2 shall be performed, at the same test age, on each of these batches, and the same method of curing shall be used for all of the test specimens.

3.4 Each batch of concrete shall be tested in the plastic state for air, consistency and yield. Each batch shall be adjusted as necessary to produce a plastic concrete having an air content, consistency, and yield equal to the specified value plus or minus a reasonable laboratory working tolerance. The following tolerances shall be used as a guide: Air Content, ± ½ percent; Consistency, ± ½ in. (± 12 mm) of slump; Yield, ± 2 percent.

3.5 When the properties of a concrete batch have been established within acceptable limits, seven 6 by 12 in. (150 by 300 mm) cylinders shall be made from each batch produced in Section 3.3 (or 3.3.1) and 3.3.2 and tested in compression at the following ages: one cylinder at age 24 hours ± 4 hours (the exact age to the nearest hour at time of test shall be noted on the report); one cylinder at age 3 days; one cylinder at age 7 days; one cylinder at age 14 days; and three cylinders at age 28 days. The values of the physical properties of each mix shall be the average of the physical properties established in each of the two batches produced in Section 3.3 (or 3.3.1). These values shall be listed in Attachment 3.

3.5.1 If it is desired to use 4 by 8 in. (100 by 200 mm) cylinders as the basis for acceptance or early strength determination in the field, in accordance with Section 601.4.4, then seven 4 by 8 in. (100 by 200 mm) cylinders shall be fabricated and tested as outlined in Section 3.5 for both of the trial batches at the minimum cement factor in addition to the seven 6 by 12 in. (150 by 300 mm) cylinders.

3.5.1.1 If the average compressive strength of the six 28-day 4 by 8 in. (100 by 200 mm) cylinders for the batches at the minimum cement factor is not more than 10.0 percent greater than the average compressive strength of the six 28-day 6 by 12 in. (150 by 300 mm) cylinders for the batches at the minimum cement factor, then 4 by 8 in. (100 by 200 mm) cylinders will be permitted to be used in the field. Otherwise, any cylinders fabricated in the field for acceptance or early strength determination must be 6 by 12 in. (150 by 300 mm) cylinders.

3.5.1.2 The following formula shall be used during the mix design approval process to determine if the average compressive strength of the three 28-day 4 by 8 in. (100 by 200 mm) cylinders is greater than 110.0 percent of the average compressive strength of the three 28-day 6 by 12 in. (150 by 300 mm) cylinders:

If $\bar{X}_{4x8} > \bar{X}_{6x12} \times 1.10$, then 4 by 8 in. (100 by 200 mm) cylinders are not permitted to be used in the field.

Where:

$\bar{X}_{6x12}$ = Average 28-day compressive strength of 6 by 12 in. (150 by 300 mm) cylinders.

$\bar{X}_{4x8}$ = Average 28-day compressive strength of 4 by 8 in. (100 by 200 mm) cylinders.

3.5.2 The following properties of each batch of concrete produced in Sections 3.3 (or 3.3.1) and 3.3.2 shall be listed in Attachment 2: A-bar of total solids, consistency, air content, unit weight and yield, water-cement ratio, and temperature.

3.6 Mix design submittal packages including Attachments 1, 2, and 3, A-bar worksheet(s), and raw data pertaining to the compressive strength tests shall be submitted to the WVDOH District Materials Section in which the Source (i.e. Concrete Batch Plant) is located. These submittal packages may be submitted to the District electronically, and MCS&T Division may be copied on the electronic submittal also, as this may expedite the process.

3.6.1 In the case of mix design submittals for a single mix design which is used at multiple concrete plants, one submittal package (for the same design) may be used for multiple concrete plants. All of the concrete plants at which the mix design is being used shall be noted on Attachment 1, and each WVDOH Materials Section in which the concrete plants are located shall be included on the submittal. This submittal will be reviewed by MCS&T Division, and if the mix design is approved, a separate lab number will be assigned to the mix design for each location at which it is approved.

4. ACCEPTANCE CRITERIA

4.1 If the standard deviation of the concrete plant production has been established, the mix design must have an average laboratory compressive strength, based on the 6 by 12 in. (150 by 300 mm) cylinder results equal to or greater than the "Design 28-Day Compressive Strength" required by the specifications plus two times the standard deviation. Data used to establish the standard deviation shall be taken from the Division's data bank and shall consist of at least 30 individual test results obtained from recent plant production of concrete with proportions similar to the design mix. Information relative to the statistics for a particular plant will be furnished to the Contractor upon request.

4.2 If the standard deviation of the concrete plant production has not been established, or in the case of mobile mixer units, the mix design must have an average laboratory compressive strength equal to or greater than the "Design 28-Day Compressive Strength" plus 1,300 psi (9 MPa).

4.2.1 Note that the "Design 28-Day Compressive Strength" required by the Specifications is the minimum field strength sought in 6 by 12 in. (150 by 300 mm) or 4 by 8 in.

(100 by 200 mm) cylinders representing the concrete being placed in the field, and should not be confused with the laboratory compressive strengths required for design.

5. PROPORTIONING DESIGN MIX

5.1 If the average of the batches produced in Section 3.3 (or 3.3.1), with the specified minimum cement factor, satisfies the acceptance criteria of Section 4, then it will be considered acceptable as the mix design for the class of concrete being designed.

5.2 If the average of the batches produced in Section 3.3 with the specified minimum cement factor does not satisfy the acceptance criteria of Section 4, then a linear compressive strength-cement factor relationship will be established using the average 28-day compressive strength, based on the 6 by 12 in. (150 by 300 mm) cylinder results, of the batches with the minimum cement factor and the average 28-day compressive strength of the batches with the minimum cement factor plus one bag of cement. This relationship will be interpolated to determine a cement factor [to the nearest 1 lb (2.2 kg)] which would cause the acceptance criteria to be satisfied. This interpolated cement factor will be considered acceptable for proportioning the mix design for the class of concrete being designed.

5.2.1 If neither of the averages of the batches produced in Section 3.3 satisfies the acceptance criteria of Section 4, then that proposed mix design cannot be considered as acceptable, and a new mix design will be required.

5.2.2 Section 5.2 does not apply to Class H concrete or specialized overlay concrete. Therefore, if the average compressive strength of the Class H or specialized overlay concrete batches in Section 3.3.1 does not satisfy the acceptance criteria of Section 4, then that proposed mix design cannot be considered as acceptable, and a new mix design will be required.

5.3 The submittal for a proposed mix design shall include completed copies of Attachments 1 and 3. It shall also include a completed copy of Attachment 2 for each of the batches at the minimum cement factor, and a completed copy of Attachment 2 for each of the batches at the minimum cement factor plus one bag of cement, when applicable. All pertinent information supporting these attachments and pertaining to the information in them shall be submitted also.

5.4 Although the Contractor has satisfied all requirements for concrete design and a mix design has been approved by the Engineer, the Contractor may still be required to adjust the approved mix design in the field as necessary to maintain all properties within the limits of the specification. These field adjustments shall include increasing the cement factor above the value specified in the approved mix design if such an adjustment would be necessary to cause the strength of the field placed concrete to conform to the requirements of the specification.

6. MIX DESIGN RE-APPROVAL

6.1 Each mix design shall remain approved for a period of three years from the date of approval, after which the mix design may be re-approved for an additional three years based on re-qualification tests outlined in Section 6.2 and conducted at the Concrete Producer. If a mix design is used often enough (at least fifteen air content, slump, and compressive strength tests for the previous three year period), the re-qualification tests shall not be required, and the mix design may be re-approved based on the actual field tests performed during the previous three year period.

6.1.1 When a Concrete Producer desires to have a mix design re-approved, he shall submit a written request to the WVDOH District Materials Section in which that plant is located noting such and including the current mix design lab number. The WVDOH District Materials personnel shall verify whether or not there are a minimum of fifteen air content, slump, and compressive strength tests for that mix design in the previous three year period.

6.1.2 If there are at least fifteen air content, slump, and compressive strength tests for that mix design in the previous three year period, then the WVDOH District Materials personnel shall notify MCS&T Division that the subject mix design may be re-approved based on the criteria in Section 6.1. MCS&T Division shall then update the approval date of the subject mix design.

6.1.3 If there are not at least fifteen air content, slump, and compressive strength tests for that mix design in the previous three year period, then the WVDOH District Materials personnel shall notify the Concrete Producer that the subject mix design must be re-approved as outlined in Section 6.2.

6.2 The following procedures shall be used to re-approve concrete mix designs that do not meet the criteria in Section 6.1.

6.2.1 The Concrete Producer shall provide a statement to the Engineer verifying that all sources of materials used in the approved mix designs are unchanged and the same as used in the original approved mix design. All materials shall meet the applicable sections of the specifications.

6.2.2 Coarse and fine aggregate samples shall be obtained at the Concrete Producer's facility in accordance with MP 700.00.06, and the following tests shall be conducted on those aggregate samples by a WVDOH certified Aggregate Inspector: specific gravity (both coarse and fine aggregate), combined A-bar of total solids, absorption (both coarse and fine aggregate), fineness modulus (fine aggregate), and unit weight (coarse aggregate). The results of these tests shall be used by a WVDOH certified PCC Technician at the Concrete Producer to establish a new target A-bar for the mix design and, if necessary, to adjust any batch volumes.

6.2.3 The Concrete Producer shall then, at the Producer's facility and in the presence of WVDOH District Materials personnel, produce a representative batch (acceptable to both the Producer and the WVDOH personnel) in accordance with Sections 601.6 and 601.7, of no less than 6 yd^3 (4.6 m^3) of the concrete mix subject for re-approval. This batch shall be tested for air content, slump, unit weight and yield. Also, three 6 by 12 in. (150 by 300 mm) 28-day compressive strength specimens, and if applicable, two rapid chloride permeability specimens (each to be tested at an age of 90 days or earlier and the average result used) shall be fabricated and tested from this batch.

6.2.4 If a Concrete Producer desires to have the option of using 4 by 8 in. (100 by 200 mm) cylinders in the field for a mix design which has already been approved, then at the time of mix design re-approval, or at any time prior to that time three additional 6 by 12 in. (150 by 300 mm) 28-day compressive strength specimens and six 4 by 8 in. (100 by 200 mm) 28-day compressive strength specimens shall be fabricated and tested from the batch produced in Section 6.2.3. The six 6 by 12 in. (150 by 300 mm) cylinders shall then be compared to the six 4 by 8 in. (100 by 200 mm) cylinders as outlined in Section 3.5.1.1 in order to determine if 4 by 8 in. (100 by 200 mm) cylinders will be permitted in the field for the subject mix design.

6.3 The Concrete Producer shall record the results of all tests required and the proportions used in the batch outlined in Section 6.2 in the applicable sections of Attachments 1, 2, and 3. The Concrete Producer shall then submit those attachments, along with the test data required in Section 6.2.2 to the WVDOH District Materials section, who will then forward them to MCS&T Division for evaluation. Based on these results, the existing mix design will either be re-approved (possibly with slight adjustments), or the current mix design will be considered to have expired and a new mix design will be required. When a mix design is re-approved by MCS&T Division, the laboratory approval number for that mix shall not be changed, but the approval date (the "Date Sampled") shall be revised.

6.3.1 For mix design re-approval purposes, the compressive strength of the representative batch produced in Section 6.2.3 must meet or exceed the "Design 28-day Compressive Strength" in Section 601.3, but it does not have to meet the "overdesign" acceptance criteria outlined in Section 4.

6.3.2 For mix design re-approval purposes, the average of the two rapid chloride permeability test results from the representative batch produced in Section 6.2.3 must be 1,000 coulombs or less in order for the mix design to be re-approved.

6.3.3 If a mix design has expired, it may still be used on projects which have started before the mix design expired. However, after its date of expiration, a mix design may not be used on any new projects; a new mix design shall be required for these projects.

7. CHANGING A COMPONENT MATERIAL USED IN A MIX DESIGN

7.1 Whenever more than one component material in an approved mix design is changed simultaneously, a new laboratory mix design, in accordance with Section 3 shall be required.

7.1.1 There are circumstances when one component material in an approved mix design may be changed to another WVDOH approved component material without requiring a new laboratory mix design. Those circumstances, and the subsequent steps which must be taken in order for that component material change to be approved, are outlined in the following sections.

7.2 The changes, outlined below, to any of the following component materials are permitted provided the requirements in Section 7.3 are met. Only one component material may be changed at a time, otherwise a new laboratory mix design in accordance with Section 3 shall be required. When changing the type and/or source of any one component material, minor adjustments to the quantities of other component materials in the mix design are permitted, in order to maintain desired mix properties.

7.2.1 Cement: The source of cement may be changed provided the requirements of Section 7.3 are met.

7.2.2 Pozzolan: The source and/or type of pozzolan may be changed provided the requirements of Section 7.3 are met.

7.2.3 Chemical Admixture: The source and/or type of any individual admixture (*i.e.*, air entraining, water reducing, or water-reducing and retarding, *etc.*) may be changed provided the requirements of Section 7.3 are met. If more than one admixture is used in a mix design, a change to an individual component material means a change in only one of those admixtures. If more than one admixture is used in a mix design, and a change to one of these admixtures is desired (a change to an individual component material), then the source of the new admixture must still be the same as the source of the rest of the admixtures in the mix (*i.e.*, water-reducing admixture A from Source X may be changed to water-reducing admixture B from Source X.)

7.2.4 Latex Admixture: The source of latex admixture may be changed provided the requirements of Section 7.3 are met.

7.2.5 Fine Aggregate: The source of fine aggregate may be changed provided the requirements of Section 7.3 are met. However, if the type of fine aggregate changes (*i.e.*, silica sand to limestone sand or natural sand to manufactured sand), a new laboratory mix design in accordance with Section 3 shall be required.

7.2.6 Coarse Aggregate: The source of coarse aggregate may be changed provided the requirements of Section 7.3 are met. However, if the type or size of coarse aggregate changes (*i.e.*, river gravel to limestone or #57 limestone to #67 limestone), a new laboratory mix design in accordance with Section 3 shall be required.

7.3 When a change to any individual component material in an approved mix design, as outlined in Sections 7.1.1 and 7.2, is desired, the Concrete Producer shall, at the Producer's facility and in the presence of WVDOH District Materials personnel, produce two separate representative batches (acceptable to both the Producer and the WVDOH personnel) in accordance with Sections 601.6 and 601.7. Each of these batches shall be no less than 3 yd^3 (2.3 m^3), shall be batched at the target cement factor, and shall consist of the concrete mix with the proposed material change. The proportions for these batches shall be determined by a WVDOH certified PCC Technician.

7.3.1 If there is a change to either the coarse or fine aggregate, then a sample of the new material shall be obtained at the Concrete Producer's facility in accordance with MP 700.00.06, and the following tests shall be conducted by a WVDOH certified Aggregate Inspector on that aggregate sample: specific gravity, solid A-bar of the new material and A-bar of total solids, absorption, fineness modulus (fine aggregate), and unit weight (coarse aggregate). The results of these tests shall be used by a WVDOH certified PCC Technician at the Concrete Producer to establish a new target A-bar for the mix and, if necessary, to adjust any batch volumes.

7.3.2 In lieu of the two batches produced at the Producer's facility, as outlined in Section 7.3, two batches may be produced at a Division Approved Laboratory, meeting the requirements of Section 3.1. These batches do not need to be witnessed by WVDOH personnel. The sizes of these batches shall be the same as the size of the batches produced for new laboratory mix designs, and their proportions shall be determined by certified laboratory personnel. If there are any changes to either the coarse or fine aggregate, certified laboratory personnel may perform the testing and mix adjustments as stated in Section 7.3.1.

7.3.3 All of the information pertaining to the materials used in these batches shall be listed in Attachments 1, 2, and 3 as outlined in Section 3.2.

7.3.4 Both batches of concrete shall be tested in the plastic state for air, consistency, and yield. Each batch shall be adjusted as necessary to produce a plastic concrete having an air content, consistency, and yield equal to the specified value plus or minus the following tolerances: Air content, ± 1 percent; Consistency, ± 1 in. (± 25 mm) of slump; Yield, ± 2 percent.

7.3.4.1 If laboratory batches are produced in lieu of batches at the Producer, as outlined in Section 7.3.2, then the batch tolerances specified in Section 3.4 shall apply.

7.3.5 When the properties of a concrete batch have been established within acceptable limits, three 6 by 12 in. (150 by 300 mm) cylinders shall be made from each batch produced in Section 7.3 and tested in compression at an age of 28 days. The values of the physical properties of this new mix design (with the component material change) shall be the average of the physical properties established in the two batches produced in Section 7.3. These values shall be listed in the column for the mix with the "Minimum Cement Factor" in Attachment 3.

The following properties of each batch of concrete produced in Section 7.3 shall be listed in Attachment 2: A-bar of total solids, consistency, air content, unit weight and & yield, water-cement ratio, and temperature.

7.4 When it is desired to change a component material in a mix which requires the rapid chloride permeability test (Class H concrete and specialized concrete overlays as outlined in Section 679), a minimum of one permeability specimen shall be fabricated from each of the batches produced in Section 7.3. The average value of these permeability specimens shall be no more than 10 percent greater than the mix design permeability value, required in the applicable specification, when tested at the time frame specified in the applicable specification.

7.4.1 If laboratory batches are produced in lieu of batches at the Producer, as outlined in Section 7.3.2, then the average value of these permeability specimens shall be less than or equal to the mix design permeability value required in the applicable specification, when tested at the time frame specified in the applicable specification.

7.5 If 4 by 8 in. (100 by 200 mm) cylinders were approved for use with the mix design which was approved prior to the component material change, then 4 by 8 in. (100 by 200 mm) cylinders shall also be approved for use with the new mix (with the component material change) with no further testing required.

7.5.1 Otherwise, if it is desired to use 4 by 8 in. (100 by 200 mm) cylinders as the basis for acceptance or early strength determination in the field with the new mix (with the component material change) then three 4 by 8 in. (100 by 200 mm) 28-day compressive strength specimens shall be fabricated and tested from each of the batches produced in Section 7.3. The six 6 by 12 in. (150 by 300 mm) cylinders from these batches shall then be compared to the six 4 by 8 in. (100 by 200 mm) cylinders from these batches as outlined in Sections 3.5.1.1 and 3.5.1.2 in order to determine if 4 by 8 in. (100 by 200 mm) cylinders will be permitted in the field for the subject mix design.

7.6 The average compressive strength of the two batches produced at the Producer in Section 7.3 must have an average compressive strength which exceeds the "Design 28-Day Compressive Strength" required by the specifications by the value (f'_{cr})

obtained from the formula below. The criteria used to establish the standard deviation is outlined in Section 4.1.

$f'_{cr} = f'_c + 2.33\sigma - 500$

Where:
f'_{cr} = Required average compressive strength of the batches produced in Section 7.3 (expressed in psi)
f'_c = Design 28-Day Compressive Strength (expressed in psi)
σ = Concrete Plant Standard Deviation (outlined in Section 4.1)

7.6.1 If laboratory batches are produced in lieu of batches at the Producer, as outlined in Section 7.3.2, then the average compressive strength of these batches must have an average compressive strength which exceeds the "Design 28-Day Compressive Strength" required by the specifications by the value (f'_{cr}) obtained from the formula below. The criteria used to establish the standard deviation is outlined in Section 4.1.

$f'_{cr} = f'_c + 2\sigma$

7.6.2 If the average compressive strength of the two batches produced in Section 7.3 (f'_{cr}) is less than the "Design 28-Day Compressive Strength" (f'_c) required by the specifications, the new mix (with the component material change) cannot be considered as acceptable, unless the requirements of Section 7.7 are met.

7.7 It is not required, but if the Concrete Producer desires, two additional separate batches may be produced, at the same time that the two batches in Section 7.3 are being produced. These two additional batches shall be acceptable to both the Producer and the WVDOH personnel, and shall be produced in accordance with Sections 601.6 and 601.7. Each of these batches shall be no less than 3 yd^3 (2.3 m^3), shall be batched at the target cement factor plus one bag of cement [94 lb (42.6 kg)], and shall consist of the concrete mix with the proposed material change.

7.7.1 In lieu of the two batches produced at the Producer's facility, as outlined in Section 7.7, two batches at the target cement factor plus one bag of cement [94 lb (42.6 kg)] may be produced at a Division Approved Laboratory, meeting the requirements of Section 3.1. These batches, produced at a Division Approved Laboratory, do not need to be witnessed by WVDOH personnel. The sizes of these batches shall be the same as the size of the batches produced for new laboratory mix designs, and their proportions shall be determined by certified laboratory personnel.

7.7.2 Production of these two additional batches is not an option for Class H concrete or specialized overlay concrete.

7.7.3 Both batches of concrete shall be tested in the plastic state for air, consistency and yield. Each batch shall be adjusted as necessary to produce a plastic concrete having an air content, consistency, and yield equal to the specified value plus or minus the following tolerances: Air Content, ± 1 percent; Consistency, ± 1 in. (± 25 mm) of slump; Yield, ± 2 percent.

7.7.3.1 If laboratory batches are produced in lieu of batches at the Producer, as outlined in Section 7.7.1, then the batch tolerances specified in Section 3.4 shall apply.

7.7.4 When the properties of a concrete batch have been established within acceptable limits, three 6 by 12 in. (150 by 300 mm) cylinders shall be made from each batch produced in Section 7.7 and tested in compression at an age of 28 days. The values of the physical properties of this new mix design (with the component material change) shall be the average of the physical properties established in the two batches produced in Section 7.7. These values shall be listed in the column for the mix with the "Minimum Cement Factor + 1 Bag" in Attachment 3.

The following properties of each batch of concrete produced in Section 7.7 shall be listed in Attachment 2: A-bar of total solids, consistency, air content, unit weight and yield, water-cement ratio, and temperature.

7.7.5 If the average of the batches produced in Section 7.3, with the specified target cement factor, does not satisfy the acceptance criteria set forth in Section 7.6, then a linear compressive strength-cement factor relationship will be established using the average 28-day compressive strength [based on the 6 by 12 in. (150 by 300 mm) cylinder results] of the batches with the target cement factor (Section 7.3) and the average 28-day compressive strength of the batches with the target cement factor plus one bag of cement (Section 7.7). This relationship will be interpolated to determine a cement factor [to the nearest 1 lb (2.2 kg)] which would cause the acceptance criteria to be satisfied. This interpolated cement factor will be considered acceptable for proportioning the design mix for the class of concrete being designed.

7.7.6 If neither of the averages of the batches produced in Sections 7.3 or 7.7 satisfy the acceptance criteria in Section 7.6, then that proposed component material change cannot be considered as acceptable, and a new laboratory mix design will be required in order to make a change in component materials.

7.8 The submittal for a proposed mix design change, as outlined in Section 7, shall include completed copies of Attachments 1 and 3. It shall also include a completed copy of Attachment 2 for each of the batches produced in Section 7. All pertinent information supporting these attachments and pertaining to the information in them shall be submitted also. This new mix design shall be submitted to the District in the same manner as a normal mix design, and it shall then be forwarded to MCS&T

Division for review and approval. If approved, a new lab number will be assigned to this mix design, and it shall, from that point forward be treated as a new mix design.

7.9 No additional component material changes are permitted to this mix design (without a new laboratory mix design) until there are a minimum of 20 consecutive field test results, from this new mix design, which meet or exceed the design compressive strength requirements. Once there are 20 consecutive field test results, from this new mix design, which meet or exceed the design compressive strength requirements, this mix design is eligible for another component material change in accordance with Section 7.

8. REPLACEMENT OF FLY ASH WITH CEMENT IN A MIX DESIGN

8.1 When an issue arises with a fly ash source or any other circumstance arises which causes a Concrete Producer to discontinue the use of a source of fly ash in an approved mix design, and not substitute another source of fly ash for the one being discontinued, an equal volume of cement may be substituted for the fly ash in that mix.

8.1.1 This option of replacing fly ash with cement does not apply to Class H concrete and concrete for specialized overlays, as set forth in Section 679 of the specifications.

8.2 The Concrete Producer shall notify the WVDOH District Materials personnel that it is desired to replace the fly ash in an approved concrete mix design with an equal volume of cement. The WVDOH District Materials personnel may then approve this change on a temporary basis. Field test data, as outlined in the following sections, shall be used to approve this mix design change as a permanent new mix design.

8.3 Two batches of concrete, produced with this mix containing all cement and no fly ash shall then be tested in the presence of WVDOH District Materials personnel. Both of these batches of concrete shall be tested in the plastic state for air, consistency, and yield. Each batch shall have an air content, consistency, and yield equal to the specified value plus or minus the following tolerances: Air content, ± 1 percent; Consistency, ± 1 in. (± 25 mm) of slump; Yield, ± 2 percent.

8.3.1 Three 6 by 12 in. (150 by 300 mm) cylinders shall be made from each batch outlined in Section 8.3 and tested in compression at an age of 28 days. The values of the physical properties of this new mix design (with the fly ash replacement) shall be the average of the physical properties established in the two batches produced in Section 8.3. These values shall be listed in the column for the mix with the "Minimum Cement Factor" in Attachment 3.

The following properties of each batch of concrete produced in Section 8.3 shall be listed in Attachment 2: A-bar of total solids, consistency, air content, unit weight and & yield, water-cement ratio, and temperature.

8.4 The average compressive strength of the two batches produced in Section 8.3 must have an average compressive strength which exceeds the "Design 28-Day Compressive Strength" required by the specifications.

8.5 The submittal for a mix design change from a mix containing fly ash to a mix using only cement as the cementitious material, as outlined in Section 8, shall include completed copies of Attachments 1 and 3. It shall also include a completed copy of Attachment 2 for each of the batches produced in Section 8.3. All pertinent information supporting these attachments and pertaining to the information in them shall be submitted also. This mix design change submittal shall be submitted to the District in the same manner as a normal mix design, and it shall then be forwarded to MCS&T Division for review and approval. A new lab number will be assigned to this mix design, and it shall, from that point forward be treated as a new mix design, using only cement as the cementitious material.

9. ADDITION OF HYDRATION CONTROL STABILIZING ADMIXTURES TO EXISTING MIX DESIGNS

9.1 Approved Hydration Control Stabilizing Admixtures, as specified in Section 707.15, designed to stop the hydration of cement in a concrete mix, enabling an extension to the allowable discharge time from a truck mixer as outlined in Section 601.7 of the Specifications may be added to an existing approved concrete mix design in accordance with the procedures outlined in this Section.

9.2 Two separate batches of concrete shall be produced as outlined in Section 7.3. These concrete batches shall be tested as outlined in Sections 7.3 and 7.4.

9.2.1 Additional testing, as outlined in the second, third, and fourth paragraphs of Section 707.15.2.1, shall also be performed on one of the batches produced in Section 9.2 in order to verify that the allowable concrete discharge time may be extended.

9.3 If the requirements set forth in Section 7.6 are met, then the procedures set forth in Sections 7.8 and 7.9 shall be followed, and the existing mix shall be approved for use with the hydration control stabilizing admixture, and a new lab number will be assigned to this mix design.

9.4 No additional changes to the existing mix design are permitted at the time that these concrete batches are being produced for the acceptance of the addition of the hydration control stabilizing admixture to the existing mix design.

Paul M. Farley , P. E.
Acting Director
Materials Control, Soils & Testing Division

PMF:MI

Attachments

Source:		Source Code:	
Source Location:		Producer/Supplier Code:	
Class of Concrete:		Materials Code:	
		SiteManager Mat. Code:	
Design Laboratory:		Date:	

Cementitious Material Data			
Data	Cement	Pozzolan 1	Pozzolan 2
Name			
Type			
Materials Code			
SiteManager Mat. Code			
Source			
Source Location			
Source Code			
Producer/Supplier Code:			
Specific Gravity			

Admixture Data			
Data	Air Entrainment	Additional Admixture 1	Additional Admixture 2
Name			
Type			
Materials Code			
SiteManager Mat. Code			
Source			
Source Location			
Source Code			
Producer/Supplier Code:			

Aggregate Data		
Data	Coarse Aggregate	Fine Aggregate
Class/Size		
Type		
Materials Code		
SiteManager Mat. Code		
Source		
Source Location		
Source Code		
Producer/Supplier Code:		
Specific Gravity		
A-Bar		
Absorption		
Fineness Modulus		
Unit Weight		

Source: ____________________

Source Location: ____________________

Design Laboratory: ____________________

Class of Concrete: ____________________

Date: ____________________

Check The Appropriate Box For Designated Batch:	Minimum Cement Factor		Mininimum Cement Factor + 1 Bag		Additional Batch
	Batch 1	Batch 2	Batch 1	Batch 2	

Material	Mass	Units	Volume		Units
Cement		lb (kg)			ft^3 (m^3)
Pozzolan 1		lb (kg)			ft^3 (m^3)
Pozzolan 2		lb (kg)			ft^3 (m^3)
Latex Admixture		lb (kg)	gal (L)		ft^3 (m^3)
Water		lb (kg)	gal (L)		ft^3 (m^3)
Air Content, by volume		%			ft^3 (m^3)
Coarse Aggregate		lb (kg)			ft^3 (m^3)
Fine Aggregate		lb (kg)			ft^3 (m^3)
Total		lb (kg)			ft^3 (m^3)
Air Entrain. Admixture		oz/Cwt (mL/100kg)			fl. oz. (mL)
Chemical Admixture 1		oz/Cwt (mL/100kg)			fl. oz. (mL)
Chemical Admixture 2		oz/Cwt (mL/100kg)			fl. oz. (mL)

Mixture Test Data							
A Total Solids	W/C Ratio	Cement Factor (ft^3)	Temperature	Consistency	Air Content	Unit Weight	Yield

Compressive Stength, psi (MPa)			
Specified Test Age:	Actual Test Age (hours)	6" x 12" (150 x 300 mm) Strengths	4" x 8" (100 x 200 mm) Strengths
24 ± 4 Hours			
3 Days			
7 Days			
14 Days			
28 Days			
28 Days			
28 Days			
Avg. 28 Day Strength			

Rapid Chloride Permeability Testing (When Applicable)		
Method of Curing (Check Applicable Box)	Standard	Accelerated
	Age at Time of Test (Days)	Total Adjusted Charge Passed (Coulombs)
Test 1		
Test 2		
Average		

SUMMARY

Source: ____________________
Source Location: ____________________
Design Laboratory: ____________________
Class of Concrete: ____________________
Date: ____________________

	Minimum Cement Factor		Minimum Cement Factor + 1 Bag	
Material	Mass	Units	Mass	Units
Cement		lb (kg)		lb (kg)
Pozzolan 1		lb (kg)		lb (kg)
Pozzolan 2		lb (kg)		lb (kg)
Water		lb (kg)		lb (kg)
Coarse Aggregate		lb (kg)		lb (kg)
Fine Aggregate		lb (kg)		lb (kg)
Total		lb (kg)		lb (kg)
Air Entrain Admixture		oz/Cwt (mL/100kg)		oz/Cwt (mL/100kg)
Chemical Admixture 1		oz/Cwt (mL/100kg)		oz/Cwt (mL/100kg)
Chemical Admixture 2		oz/Cwt (mL/100kg)		oz/Cwt (mL/100kg)
Total A Bar Solids				
Water Cement Ratio				
Cement Factor				
Temperature		°F (°C)		°F (°C)
Consistency		inches (mm)		inches (mm)
Air Content		%		%
Unit Weight		lb/ft^3 (kg/m^3)		lb/ft^3 (kg/m^3)
Yield		ft^3 (m^3)		ft^3 (m^3)
Aggregate Correction Factor per AASHTO T 152		%		%

Compressive Strength, psi (Mpa)	Minimum Cement Factor Batch 6" x 12" Cyl. (150x300 mm)	Minimum Cement Factor Batch 4" x 8" Cyl. (100x200 mm)	Minimum Cement Factor + 1 Bag Batch
1 Day			
3 Days			
7 Days			
14 Days			
28 Days			
28 Days			
28 Days			
Avg. 28 Day Strength			
If applicable, are 4" x 8" (100 x 200 mm) cylinders permitted in the field.			

Average Value of Rapid Chloride Permeability Test (Coulombs):	

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

MAINTAINING SPECIFIED LEVEL OF STRENGTH IN PORTLAND CEMENT CONCRETE

1.0 PURPOSE

The purpose of this procedure is to set forth a method of adjusting the cement content of portland cement concrete so that a reasonable conformance with the specified level of strength may be assured.

2.0 SCOPE

The procedure shall apply to all classes of concrete except pavement concrete (pavement concrete may also be treated in the manner specified herein providing the Contractor has a suitable means of verifying the minimum 28-day design strength, and providing a copy of the plan for verifying the strength is submitted to and is approved by the Engineer).

3.0 PROCEDURE

3.1 Initial Cement Requirement

3.1.1 "Initial Cement Requirement" is the cement requirements determined by formal laboratory design methods such as MP 711.03.23 or other suitable and approved methods.

3.2 Reevaluating Cement Requirement

3.2.1 A concrete mix design referred to herein means a combination of particular source and type of materials and a cement factor which satisfies the requirement of the governing specification, said combination of materials and cement factor being formulated for the express purpose satisfying the requirement of a particular class of concrete specified for the work. The cement factor in a particular mix design may be changed without invalidating the design. If source or type of materials in a mix design are changed, however, the mix design is changed and two or more mix designs would result therefrom.

Strength data which represents two cement factors in one mix design may be processed collectively in the derivation of statistical parameters, average and standard deviation, for example, if it is felt that such a treatment does not significantly affect the statistics.

3.2.2 For the various classes of concrete which are designed in conformance with MP 711.03.23, the first reevaluation of cement requirement shall be made after at least ten pieces of strength data are available to evaluate the adequacy of the mix design. Thereafter, a reevaluation of cement requirement shall be made at monthly intervals at which time, the evaluation shall be based on the strength data developed during the preceding two months or on the last ten pieces of data developed, whichever is greater.

3.3 Method of Evaluating Cement Requirement

3.3.1 The cement requirement for all classes of concrete governed by this procedure shall be the quantity necessary to maintain the strength of the concrete in the range of the Design Strength (f'_c) plus K_1 standard deviations and the Design Strength (f'_c) plus K_2 standard deviations $(f'_c+K_1s)<X<(f'_c+K_2s)$. The average (X) and the standard deviation (s) shall be calculated using the strength data developed during the previous two months or the last ten pieces of strength data, whichever is greater.

3.3.2 If the strength of concrete can be maintained at a level which is equal to or greater than the Design Strength plus K_2 standard deviations $(f'_c+K_2s)<X$, then the cement factor which causes this level of strength to be developed may be reduced as indicated in Article 3.3.4.3 except that in no instance shall the cement factor be reduced below a level of the target specified cement factor less 28kg of cement per cubic meter.

3.3.3 If the strength of the concrete is maintained below the level of the Design Strength plus K_1 standard deviations, $X < (f'_c+K_1s)$, then the cement factor which causes this level of strength to be developed shall be increased as indicated in Article 3.3.4.2.

3.3.4 The relationship between the level of concrete strength (considered to be the average of all data developed during the preceding two months or the average of the last ten pieces of strength data, whichever is greater, and represented by X), and the action which must be taken regarding the cement factor is as follows:

3.3.4.1 If the average strength is maintained at a level between the Design Strength plus K_1 standard deviations and the Design Strength plus K_2 standard deviations $\{(f'_c+K_1s)<X<(f'_c+K_2s)\}$ the cement factor shall be continued without change.

3.3.4.2 If the average strength falls below the Design Strength, plus K_1 standard deviations $\{X<(f'_c+K_1s)\}$ the cement factor shall be increased in accordance with the following formula:

$$C_i = \frac{(f'_c+K_1s)-X}{1.4}$$

Where C_i = Number of 14kg increments of cement increase per cubic meter, rounded up to a whole number.

f'_c = Design Strength

K_1 = Factor from Table 1.

s = Standard Deviation

X = Average Strength

3.3.4.3 If the average strength falls above the Design Strength plus K_2 standard deviations $\{X>(f'_c+K_2s)\}$ the cement factor may be decreased in accordance with the following formula:

$$C_d = \frac{X-(f'_c+K_1s)}{1.4}$$

Where C_d = Number of 14kg increments of cement decreases per cubic meter, rounded to the nearest whole number.

3.4 Reporting

Once each month, the Materials Control, Soils and Testing Division will publish a list of concrete producers (Commercial Suppliers and/or Contractors) with classes of concrete and their corresponding cement factor determined in conformance with this MP.

3.5 Reevaluating Concrete Mix Design

A concrete mix design which is approved for a particular project will remain valid to the extent that it satisfies the requirement for that particular project for its duration.

A concrete mix design which is developed in conformance with MP 711.03.23 and maintained for a period of one year during which time fewer than ten pieces of strength data are developed to evaluate the adequacy of the mix design shall become invalid after which time, it will not be approved for use on State projects. It is the Contractor's responsibility to make adjustments to the design mix as necessary to maintain in the concrete proper placability, workability, finishability, yield, air content, and other requirements of the governing specification. The Contractor should be especially aware of the responsibility when he changes the cement factor in conformance with this procedure.

Gary L. Robson, Director
Materials Control, Soils
and Testing Division

GLR:b

TABLE 1
VALUES OF "K" FACTORS

NUMBER OF PIECES OF DATA	K_1	K_2
10	1.604	3.615
11	1.588	3.510
12	1.576	3.429
13	1.565	3.365
14	1.557	3.313
15	1.549	3.270
16	1.543	3.233
17	1.538	3.202
18	1.533	3.175
19	1.528	3.151
20	1.525	3.130
21	1.521	3.112
22	1.518	3.096
23	1.515	3.081
24	1.513	3.067
25	1.511	3.055
26	1.508	3.044
27	1.507	3.034
28	1.505	3.024
29	1.503	3.016
30	1.501	3.008
Above 30	1.500	3.000

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

DEVELOPMENT AND USE OF THE EQUATION FOR PREDICTING POTENTIAL STRENGTH OF PORTLAND CEMENT CONCRETE

1.0 PURPOSE

1.1 To set forth a procedure for development of the equation for predicting the potential strength of Portland Cement Concrete from the results of early age tests on concrete cylinders.

1.2 To establish criteria for use of the results of these early tests and the resultant predicted values as a part of the Quality Assurance process.

2.0 SCOPE

2.1 This procedure may be applicable to any Portland Cement Concrete when it is desired to estimate the potential strength of that concrete.

3.0 KEY WORDS

3.1 Maturity - A term used to describe the combinations of conditions in and around a concrete cylinder that affect the strength gain of that concrete. Maturity is expressed in degree - hours. (M or m)

3.2 Degree - Hours - The age of a concrete cylinder, in hours, multiplied by the ambient temperature of that specimen - [C(hr)].

3.3 Line of Prediction - The line which represents the relationship between the logarithm of the maturity of compressive strength specimens and the strength of those specimens.

3.4 Prediction Equation - The equation, representing the line of prediction, which is used to predict the potential strength of Portland Cement Concrete from tests on compressive strength specimens at an early age.

4.0 THE GENERAL FORM OF THE PREDICTION EQUATION IS:

$S_M = S_m + b\ (\text{Log } M\text{-Log } m)$ Equation A-1

Where:

S_M is the predicted potential strength at maturity M.

S_m is the measured compressive strength at maturity m.

b is the slope of the prediction line.

M is degree-hours of maturity under standard conditions.

m is degree-hours of maturity of the specimen at time of early test ±K.

K is degree-hours of maturity determined from residual temperature and other possible unmeasurable factors which would influence the strength of the concrete.

5.0 EQUATION DEVELOPMENT

The development of the prediction equation is dependent upon development of the line of prediction.

5.1 Compressive strength data, for different ages of test, and the corresponding maturity values will generally be developed in the laboratory to determine the line of prediction for each class of concrete to be used. This data should include tests at age 24 hours, 3, 7, 14, and 28 days.

5.2 Prepare a sheet of semi-log graph paper, 3 cycle by 10 divisions. Number the 25.4 mm divisions in 10 MPa increments (y axis). The Logarithmic scale will represent maturity, in degree hours, at time of test (x axis). See Attachment 1.

5.3 Plot each of the strength values, developed as per Subsection 5.1, versus the maturity for each age of test.

5.4 Ideally the line of prediction would pass through each of the points plotted as strength versus maturity to form a straight line. (The value of 15,000? C (hr) is always used for M at 28 days). Because of the inaccuracy in determining all of the factors which affect the maturity, these points may not fall in a straight line.

5.5 A best fitting straight line shall be drawn through the plotted points making sure the line passes through the point which represents the 28 day maturity versus strength. The points representing maturity at test ages less than 28 days may not fall on a straight line which passes through the 28 day point, but it may be possible to shift these points in one direction, either to the left or the right, a certain distance (K) to cause them to better fit the straight line. In this event, the distance "K" is used in the equation set forth in Section 4 and is either added to or subtracted from the value "m" depending on whether the points were shifted to the right or to the left. Since the exact maturity is an unknown value, the constant (K) will have to be determined by trial and error.

5.6 From the line of prediction, the value (b) can be determined. The slope (b) of this line is the vertical scale distance between the intercept on the 1,000 m line and the intercept on the 10,000 m line.

5.7 The constants b and k thus developed are used in the equation (See Article 4) to predict the potential 28 day strength of Portland Cement Concrete.

6.0 EQUATION USE

6.1 The equation developed as per Article 5 may be used to predict the potential 28 day strength of any class of Portland Cement Concrete.

6.2 Compressive strength test specimens shall be fabricated in accordance with the applicable specification requirements. The specimens shall be cured for at least 24 hours. An accurate record should be maintained of the temperature immediately surrounding the specimens.

6.3 The specimens shall be removed from the molds as soon as practicable after 24 hours. The specimens shall be capped and tested in accordance with governing requirements. The exact age at time of test shall be noted. The maturity (m) of the early age test specimen is the age in hours multiplied by the ambient temperature plus the constant K [(hrs.) (°C) + K = m].

6.4 The frequency with which early age specimens are made and tested may vary but in any case, the frequency will be specified for the work being done.

7.0 PREDICTION ACCURACY

7.1 With each third set of specimens made for prediction purposes, a set of specimens shall be made and tested at the age corresponding to the maturity M. The strengths thus determined will be compared to the early age test values to verify the accuracy of the prediction equation.

7.2 The early age test value (S_m) shall have a strength equal to or greater than 5.9 MPa at 24 hours and the predicted value (S_M) shall have a strength at maturity M equal to or greater than the specified minimum plus 5.5 MPa. If the early age test value (S_m) is determined at an age other than 24 hours, then the equation set forth in Section 4 shall be used to determine the strength at 24 hours.

7.3 In the event of the first occurrence of noncompliance with Subsection 7.2, the following action shall be taken.

7.3.1 An investigation shall be immediately instituted to determine if the concrete production, sampling, sample handling, and testing are in accordance with prescribed procedures.

7.3.2 The frequency of fabricating and testing early age specimens, as prescribed for the particular work, shall be increased so that the number of specimens made during the prescribed time interval shall be doubled.

7.3.3 In conjunction with the first set of specimens fabricated after the noncompliance is determined, a set of specimens shall be fabricated for tests at the age corresponding to the maturity M.

7.4 In the event of a second consecutive occurrence of noncompliance with Subsection 7.2, the following action shall be taken.

7.4.1 Appropriate personnel of the Materials Control, Soils and Testing Division shall be promptly advised of this occurrence.

7.4.2 The investigation required in Article 7.3.1 shall be repeated.

7.4.3 Notify the Contractor immediately and in writing that two consecutive strength tests have indicated that a problem may exist and that further placement of concrete will be done at his risk.

7.4.4 Continue to make specimens for early test at the rate established in Article 7.3.2. In conjunction with the first set of specimens fabricated after the second consecutive failure, a set of specimens shall be fabricated for tests at the age corresponding to the maturity M.

7.5 In the event of a third consecutive occurrence of noncompliance with Subarticle 7.2, the following action shall be taken.

7.5.1 Appropriate personnel of the Materials Control, Soils and Testing Division shall be promptly advised of this occurrence.

7.5.2 An appropriate adjustment shall be affected in the cement factor of the concrete to insure that the concrete will comply with Subsection 7.2.

7.6 If the cement factor is increased in accordance with Article 7.5.2, then the increased cement factor shall remain in effect until the particular reason for the noncompliance is isolated and appropriate action taken to insure compliance with Article 7.5.2 or until at least ten pieces of data are developed for evaluation using the criteria set forth in MP 711.03.26. Based upon this evaluation, the Division will make an appropriate adjustment to the cement factor. In no case, however, will the cement factor be less than that cement factor determined for the source production.

7.7 The slope (b) of the prediction line can be more accurately estimated with the equation:

Equation A-2

$$b = \frac{\Sigma(S - S_m)}{\Sigma(\text{Log } M - \text{Log } m)}$$

Where:

Σ Symbol indicating that the values are to be added or totaled.

S is the measured compressive strength at maturity M.

S_m is the measured compressive strength at maturity m.

8.0 REPORTING

8.1 The strength values determined at maturity m and the resultant predicted value shall be reported as per Attachment Number 2.

8.2 If an investigation is warranted as per Subsection 7.2, then the investigation shall be reported using the standard Materials Inspection Report format.

Gary L. Robson, Director
Materials Control, Soils
and Testing Division

GLR:b

Attachments

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

CAPPING CONCRETE CYLINDERS

1.0 PURPOSE

1.1 To provide technicians and supervisory personnel with standard procedures for capping concrete cylinders.

2.0 SCOPE

2.1 This procedure details methods for capping concrete cylinders for compressive strength testing. As a normal policy all cylinders will be capped. ASTM C-617 provides for capping of freshly molded cylinders with neat portland cement pastes, and capping of hardened cylinders with high-strength gypsum plaster or sulfur mortar. All methods specified in ASTM C-617 are permitted. This procedure will detail procedure for sulfur mortar capping, steel end plates with rubber insert as described in WVDOH Research Project 52 (RP-52) and special capping procedures.

3.0 SULFUR MORTAR CAPS

3.1 Capping Equipment

3.1.1 The capping jig shall have angle iron or other suitable guides capable of aligning the cylinder to insure the perpendicularity of the cap surface to the long axis of the cylinder as set forth in ASTM C-617.

3.1.2 Capping Plates - The capping plate shall meet the requirements of ASTM C-617.

3.1.3 Melting Pot - The melting pot should be of a type as described in ASTM C-617.

3.1.4 Capping Material - The capping material shall meet the requirements of ASTM C-287.

3.2 Miscellaneous Supplies

3.2.1 Light cup grease

3.2.2 A large dipper

3.2.3 Scraper (A small putty knife is suggested)

3.2.4 Rubber mallet

3.2.5 Ball peen hammer

3.2.6 Wire brush

3.3 Preparation

3.3.1 Before capping, all loose particles must be removed from the ends of the cylinder with a wire brush; the end should be free from laitance and moisture.

3.3.2 When a sulfur type capping material is used, it should be heated until it is thick and viscous. The right temperature of the mixture for capping is determined through observation and experience. If a commercial preparation is used, the manufacturer's recommendation should be followed as to the temperature. Overheating of the mixture should be avoided as this tends to make the cap rubbery rather than brittle as desired.

3.3.3.1 Sulfur type capping materials are best heated and maintained in a molten condition in a thermostatically controlled, electrically heated pot. If the sulfur type caps are salvaged from test cylinders (not recommended) the material should be separately melted and strained through a sieve having about 3.2 mm openings before adding to the material to be used for future capping.

3.4 Procedure

3.4.1 Enough material to make the cap is poured into a lightly greased capping plate placed in a capping jig. The cylinder is held in both hands against the angle guide of the jig and then, holding it in this position, pressed firmly into the melted material. This operation should be done quickly, before solidification begins, so that the mixture will adhere to the specimen. Caps should be as thin as practical and should not flow or fracture when the specimen is tested. Allow the cylinder to remain in the jig undisturbed, until the capping material has cooled to a hardened condition, then the excess material is scraped off the top of the capping plate. The cylinder is then removed from the capping plate by gently tapping the plate with a rubber mallet. All sulfur type caps should be allowed to harden for at least two hours before the cylinder is tested.

3.4.2 If the end of the cylinder is rough or has any depression more than 6.3 mm deep, a strip of paper about 50.8 mm wide should be placed so as to form a projecting collar around the cylinder and held in place with a rubber band. Capping material can then be poured into the smooth surface. When this material has hardened, the paper collar is removed and the final capping done in the usual way.

3.5 Testing the Cap

3.5.1 Before testing a cylinder, the cap should be tested for air pockets by tapping it lightly, with the handle of a putty knife or other suitable instrument. A cap that sounds hollow in places should be removed and replaced by a good, solid cap. Solid caps are easily obtained if the capping surface is dry and clean, the mixture is at the right temperature, and the cylinder is placed immediately in the melted mixture on the capping plate. The bearing surface of a capped cylinder is checked by the use of a straightedge and a feeler gage. The straightedge is moved across both diagonals, measuring the gap between the straightedge and the cap with the feeler gage. The capped surface shall be plane within 0.05 mm. The capped surface shall meet the perpendicularity requirements of ASTM C-617. Any cap found unsuitable shall be removed by tapping the cap with a ball peen hammer.

4.0 STEEL END CAPS WITH RUBBER INSERT

4.1 Capping Equipment

4.1.1 Steel end caps - Two required from mild cast steel with an overall thickness of about 63.5 mm and an overall diameter of about 190.5 mm. Each cap has a cavity about 25 mm in depth and about 165 mm in diameter. It is recommended that handles be fabricated and welded to the cap to facilitate handling.

4.1.2 Rubber Insert - in the cavity of the steel cap insert a snugly fitting disk of rubber composition compression material of about 12.7 mm thickness. The material shall be a minimum of 50 durometer hardness rubber type material.

4.2 Procedure

4.2.1 The bottom cap shall be centered on the lower bearing block of the testing machine and the cylinder centered and placed on the rubber insert. The top cap shall then be placed over the cylinder with the rubber insert centered over and in contact with the cylinder. Laboratory experience has shown that rubber inserts should be replaced after 15 compression tests when using a 50 durometer material.

5.0 SPECIAL CAPPING PROCEDURE

5.1 Cylinders with any of the following defects shall be capped with a neat cement paste.

5.1.1 Ends of cylinders are convex by more than 0.5 mm.

5.1.2 Aggregate or other objects protrudes from the ends by more than 5.08 mm.

5.1.3 Ends differ from right angles to the specimen axis by more than 7.6 mm in the 152 mm specimen diameter.

5.1.4 Other irregularities which result in a cap thickness greater than 6.3 mm over most of the cap area.

5.2 Preparation of Specimen

5.2.1 The specimen ends should be wetted, wire brushed, and cleaned.

5.3 Procedure

5.3.1 Plastic, preshrunk, high strength cement paste ("Hydrostone" or "Hydrocal White" etc.) shall be applied, troweled to a slightly coned surface, and molded in a true plane normal to the specimen axis with a minimum practicable thickness. Molding of the specimen ends can be accomplished with a piece of plate glass. To prevent sticking of the plate glass a 50-50 mixture of lard oil and paraffin or a piece of wet paper can be applied to the plate glass.

5.3.2 Cement paste caps should be moist cured for at least several days with the specimen. If a rapid hardening cap is required, the cement paste can be accelerated as necessary with calcium chloride, soda ash, or plaster of paris. When accelerators are used, it is preferable to use moderate amounts and permit caps to harden at least 24 hours.

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Materials Control, Soils
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GLR:b

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

STANDARD METHOD OF TEST FOR DETERMINING THE QUALITY OF WATER USED WITH HYDRAULIC CEMENT

1.0 PURPOSE

1.1 To establish a standard method of test and acceptance criteria to be used in determining the quality of water used with hydraulic cement.

2.0 PURPOSE

2.1 This procedure is applicable to untreated water sources used in combination with mixtures containing hydraulic cement. An untreated water source may be defined as a source other than a treated public water system.

2.2 Treated water systems may be used without testing.

3.0 APPLICABLE DOCUMENTS

3.1 MP 642.40.20

3.2 AASHTO T 106

3.3 AASHTO T 154

3.4 AASHTO T 162

4.0 PROCEDURE

4.1 Untreated water shall be tested at the source for pH. When the pH of the water is between 4.5 and 8.5 no further testing is necessary.

4.2 If the pH is less than 4.5 or more than 8.5, all tests listed in this procedure will be conducted.

4.3 A water source whose pH is determined to be within the limits defined above may appear to be contaminated with foreign material which could have an adverse effect on the portland cement concrete. If the sampler has reason to believe that this may be the case, a sample shall be forwarded to the Materials Division for further tests as defined below. The sample shall be accompanied with the required documentation indicating the samplers reasons for requesting test.

5.0 TEST METHODS

5.1 Total Solids Content

Test shall be conducted in accordance with MP 642.40.20.

5.2 Compressive Strength

The water under test shall be compared, in mortar, with
distilled water. The proportions of dry materials in the mortar shall be 500 grams of Type III Cement, 1500 grams of graded OTTAWA sand and the amount of water sufficient to produce a flow of 110 $\pm$ 5 in 25 drops in accordance with AASHTO T 106 using the sample under test and compared to three specimens made using distilled water.

5.3 Time of Setting by Gillmore Needle

Time of set will be prepared with the test sample and Type III Cement in accordance with AASHTO T 154. A control specimen will be made with distilled water for basis comparison.

6.0 ACCEPTANCE CRITERIA FOR UNTREATED WATER SOURCES

Total Solids Content	2000 ppm*
Compressive Strength (Min% Control at 1 day)	90
Time of Set, (deviation from control) Minutes	-60 to +90

*Water containing more than 2000 ppm of total solids may be determined acceptable if compressive strength and time of set tests indicate that the solids will not adversely affect the concrete.

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GLR:d

APPENDIX B

GLOSSARY OF TERMS AND DEFINITIONS

ABSOLUTE VOLUME – The volume of material in a voidless or solid state

AIR DRY – A condition at which an aggregate particle is dry on the surface but contains moisture within the pores of the aggregate

AIR-ENTRAINED CONCRETE – Concrete that has minute air bubbles uniformly distributed throughout the mix. This is accomplished by the addition of an air-entraining admixture.

CEMENT FACTOR – The number of pounds of cement in one cubic yard of concrete (It may also be expressed in bags per cubic yard).

COARSE AGGREGATE – Aggregate usually larger than about 3/8 inch in diameter (usually referred to as stone or gravel).

CONSISTENCY- A condition of plastic concrete related to its cohesion, wetness, or flow. The consistency is usually measured by the slump test.

DRY-RODDED UNIT WEIGHT – The weight per unit volume of dry aggregate compacted in a container by rodding in three layers.

DURABILITY – The ability of hardened concrete to resist the deterioration caused by weathering (freezing, thawing, heating, cooling, wetting, drying, etc.), chemicals, and abrasions.

FINE AGGREGATE – A natural or manufactured aggregate smaller than about 3/8 inch in diameter (usually referred to as sand).

FINENESS MODULUS – An index as to the fineness or coarseness of an aggregate. The fineness modulus of fine aggregate is defined as the sum of the cumulative percentages retained on a standard set of sieves (#4, #8, #16, #30, #50, #100) divided by 100.

FREE MOISTURE – The moisture on the surface of an aggregate. The amount of free moisture is the difference between the total moisture and the absorbed moisture.

GRADATION OF AN AGGREGATE – The relative amounts of aggregate particles of various standard sizes.

HARSH MIX – A coarse mix that is difficult to place and finish. This usually indicates that the mix doesn't contain enough fine aggregate to provide a dense, workable mixture. A harsh mix segregates easily because it's not cohesive.

NOMINAL MAXIMUM SIZE OF AGGREGATE – The <u>largest</u> sieve size in the specification upon which <u>any</u> material may be retained.

OVEN DRY – The condition of an aggregate when it contains no moisture (either absorbed or free).

PORTLAND CEMENT – A manufactured product obtained by heating raw materials (limestone, marl, shale or clay, silica sand, and iron ore) together into a clinker and then grinding this clinker into a powder.

SATURATED SURFACE DRY - The condition of an aggregate at which it will neither absorb moisture from the concrete mix nor add moisture to the mix.

SIEVE ANALYSIS – A process in which an aggregate is separated into various sizes by passing it through screens of different size openings for the purpose of determining the distribution of the quantities separated.

SLUMP – A test used to measure the consistency of fresh concrete.

SPECIFIC GRAVITY – The ratio of the weight of a given material to the weight of an equal volume of water (both at the same temperature).

TOTAL MOISTURE – The sum of the moisture on the surface of an aggregate and the moisture that has been absorbed into the pores of that aggregate.

UNIT WEIGHT – The weight of a material per a unit volume of that material (lb/ft^3, etc.)

WATER-CEMENT RATIO – The weight of total water in a concrete mix divided by the weight of cement in the mix.

WELL-GRADED AGGREGATE – An aggregate that has a uniform percentage of material retained on each standard sieve.

WORKABILITY – The property of freshly mixed concrete that indicates the ease or difficulty in placing and finishing the concrete. “Good Workability” indicates that the mix is easily placed and finished. The slump test is not a measure of workability.

YIELD – The volume of concrete produced from one batch of materials (coarse and fine aggregate, cementitious materials, and water). Yield is calculated by dividing the total batch weight by the unit weight of the concrete.

BULK SPECIFIC GRAVITY AND ABSORPTION
COARSE AGGREGATE

A = Weight of oven-dry sample in air (grams)

B = Weight of saturated-surface-dry sample in air (grams)

C = Weight of saturated sample in water (grams)

Bulk Specific Gravity (Oven Dry Basis) $= \dfrac{A}{B - C}$

Bulk Specific Gravity (Saturated-Surface-Dry Basis) $= \dfrac{B}{B - C}$

Apparent Specific Gravity $= \dfrac{A}{A - C}$

Absorption, percent $= \dfrac{B - A}{A} \times 100$

Report Specific Gravities to the nearest 0.01

Report Absorption to the nearest 0.1%

BULK SPECIFIC GRAVITY AND ABSORPTION
FINE AGGREGATE

A = Weight of oven-dry sample in air (grams) ((a) - (b))

(a) = Weight of oven-dry sample and pan in air (grams)

(b) = Weight of pan (grams)

B = Weight of pycnometer filled to calibration mark with distilled water (grams)

C = Weight of pycnometer, sample, and water to calibration mark (grams)

D = Weight of saturated-surface-dry sample in air (grams)

Bulk Specific Gravity (Oven Dry Basis) $= \dfrac{A}{B + D - C}$

Bulk Specific Gravity (Saturated-Surface-Dry Basis) $= \dfrac{D}{B + D - C}$

Apparent Specific Gravity $= \dfrac{A}{B + A - C}$

Absorption, percent $= \dfrac{D - A}{A} \times 100$

Report Specific Gravities to the nearest 0.01

Report Absorption to the nearest 0.1%

AB = Absorption — W_D = Weight Dry

FM = Free Moisture — W_{SSD} = Weight Saturated Surface Dry

TM = Total Moisture — W_W = Weight Wet

---

1. Find: AB — Known: W_{SSD}, W_D

$$AB = W_{SSD} - W_D$$

---

2. Find: %AB — Known: W_{SSD}, W_D

$$\%AB = \left(\frac{W_{SSD} - W_D}{W_D}\right) \times 100$$

---

3. Find: W_D — Known: %AB, W_{SSD}

$$W_D = \frac{W_{SSD}}{\left(1 + \frac{\%AB}{100}\right)}$$

---

4. Find: W_{SSD} — Known: %AB, W_D

$$W_{SSD} = W_D \times \left(1 + \frac{\%AB}{100}\right)$$

---

5. Find: FM — Known: W_W, W_{SSD}

$$FM = W_W - W_{SSD}$$

---

6. Find: %FM — Known: W_W, W_{SSD}

$$\%FM = \left(\frac{W_W - W_{SSD}}{W_{SSD}}\right) \times 100$$

---

7. Find: W_{SSD} — Known: %FM, W_W

$$W_{SSD} = \frac{W_W}{\left(1 + \frac{\%FM}{100}\right)}$$

AB = Absorption
FM = Free Moisture
TM = Total Moisture

W_D = Weight Dry
W_{SSD} = Weight Saturated Surface Dry
W_W = Weight Wet

---

8. Find: W_W Known: W_{SSD}, %FM

$$W_W = W_{SSD} \times \left(1 + \frac{\%FM}{100}\right)$$

---

9. Find: TM Known: W_W, W_D

$$TM = W_W - W_D$$

---

10. Find: %TM Known: W_W, W_D

$$\%TM = \left(\frac{W_W - W_D}{W_D}\right) \times 100$$

AASHTO T-19

Table 1 – Capacity of Measures

Nominal Maximum Size Of Aggregate		Capacity of Measure[a]	
mm	in.	L (m^3)	ft^3
12.5	1/2	2.8 (0.0028)	1/10
25.0	1	9.3 (0.0093)	1/3
37.5	1 1/2	14 (0.014)	1/2
75	3	28 (0.028)	1
112	4 1/2	70 (0.070)	2 1/2
150	6	100 (0.100)	3 1/2

[a]The indicated size of measure shall be used to test aggregates of a nominal maximum size equal to or smaller than that listed. The actual volume of the measure shall be at least 95% of the nominal volume listed.

TABLE 703.4-STANDARD SIZES OF COARSE AGGREGATES (AASHTO M 43)

		Amounts finer than each laboratory sieve (square openings), percentage by weight										
Size #	**Nominal size square openings ①**	**4 (100)**	**3-½ (90)**	**3 (75)**	**2-½ (63)**	**2 (50)**	**1-½ (37.5)**	**1 (25)**	**¾ (19)**	**½ (12.5)**	**□ (9.5)**	**No.4 (4.75)**
1	3-½ to 1-½ (90 to 37.5)	100	90 to 100		25 to 60		0 to 15		0 to 5			
2	2-½ to 1-½ (63 to 37.5)			100	90 to 100	35 to 70	0 to 15		0 to 5			
24	2-½ to ¾ (63 to 19.0)			100	90 to 100		25 to 60		0 to 10	0 to 5		
3	2 to 1 (50 to 25.0)				100	90 to 100	35 to 70	0 to 15		0 to 5		
357	2 to No. 4 (50 to 4.75)				100	95 to 100		35 to 70		10 to 30		0 to 5
4	1-½ to ¾ (37.5 19.0)					100	90 to 100	20 to 55	0 to 15		0 to 5	
467	1-½ to No. 4 (37.5 to 4.75)					100	95 to 100		35 to 70		10 to 30	0 to 5
5	1 to ½ (25.0 to 12.5)						100	90 to 100	20 to 55	0 to 10	0 to 5	
56	1 to □ (25.0 to 9.5)						100	90 to 100	40 to 85	10 to 40	0 to 15	0 to 5

Size #	**Nominal size square openings ①**	**1-½ (37.5)**	**1 (25)**	**¾ (19)**	**½ (12.5)**	**□ (9.5)**	**No.4 (4.75)**	**No.8 (2.36)**	**No.16 (1.18)**	**No.50 (300 µm)**	**No.100 (150 µm)**
57	1 to No. 4 (25.0 to 4.75)	100	95 to 100		25 to 60		0 to 10	0 to 5			
6	¾ to □ (19 to 9.5)		100	90 to 100	20 to 55	0 to 15	0 to 5				
67	¾ to No. 4 (19 to 4.75)		100	90 to 100		20 to 55	0 to 10	0 to 5			
68	¾ to No. 8 (19 to 2.36)		100	90 to 100		30 to 65	5 to 25	0 to 10	0 to 5		
7	½ to No. 4 (12.5 to 4.75)			100	90 to 100	40 to 70	0 to 15	0 to 5			
78	½ to No. 8 (12.5 to 2.36)			100	90 to 100	40 to 75	5 to 25	0 to 10	0 to 5		
8	□ to No. 8 (9.5 to 2.36)				100	85 to 100	10 to 30	0 to 10	0 to 5		
89	□ to No. 16 (9.5 to 1.18)				100	90 to 100	20 to 55	5 to 30	0 to 10	0 to 5	
9	No. 4 to No. 16 (4.75 to 1.18)					100	85 to 100	10 to 40	0 to 10	0 to 5	
10	No. 4 to 0 ❷ (4.75 to 0)					100	85 to 100				10 to 30

① *In inches (millimeters), except where otherwise indicated. Numbered sieves are those of the United States Standard Sieve Series.*

❷*Screenings*

English to Metric Conversions

QUANTITY	FROM ENGLISH UNITS	TO METRIC UNITS	MULTIPLY BY
Length	mile foot inch	Km m mm	1.609344 0.3048 25.4
Area	square mile square yard square foot	km^2 m^2 m^2	2.59 0.8361274 0.092903
Volume	cubic yard cubic foot	m^3 m^3	0.764555 0.0283168
Volume (liquid)	Gallon	L	3.7854
Mass	pound ton	kg kg	0.453592 907.184
Stress	psi	MPa	0.00689476
Temperature	ºF	ºC	5/9 x (ºF - 32)

Metric to English Conversions

QUANTITY	FROM METRIC UNITS	TO ENGLISH UNITS	MULTIPLY BY
Length	km m mm	mile foot inch	0.621371 3.2808 0.03937
Area	km^2 m^2 m^2	square mile square yard square foot	0.3861 1.19599 10.76392
Volume	M^3 m^3	cubic yard cubic foot	1.30795 35.3147
Volume (liquid)	L	gallon	0.2641729
Mass	Kg kg	pound ton	2.2046 0.001102312
Stress	MPa	psi	145.0377
Temperature	ºC	ºF	(9/5 x ºC) + 32

WATER DENSITY AT VARIOUS FARENHEIT TEMPERATURES

ºF	lb/ft³	ºF	lb/ft³	ºF	lb/ft³	ºF	lb/ft³	ºF	lb/ft³
60.0	**62.366**	65.4	**62.333**	70.8	**62.295**	76.2	**62.250**	81.6	**62.200**
60.2	**62.365**	65.6	**62.332**	71.0	**62.293**	76.4	**62.249**	81.8	**62.199**
60.4	**62.364**	65.8	**62.331**	71.2	**62.292**	76.6	**62.247**	82.0	**62.196**
60.6	**62.363**	66.0	**62.329**	71.4	**62.290**	76.8	**62.245**	82.2	**62.195**
60.8	**62.362**	66.2	**62.328**	71.6	**62.289**	77.0	**62.244**	82.4	**62.193**
61.0	**62.360**	66.4	**62.327**	71.8	**62.287**	77.2	**62.242**	82.6	**62.191**
61.2	**62.359**	66.6	**62.325**	72.0	**62.286**	77.4	**62.240**	82.8	**62.189**
61.4	**62.358**	66.8	**62.324**	72.2	**62.284**	77.6	**62.238**	83.0	**62.187**
61.6	**62.357**	67.0	**62.322**	72.4	**62.282**	77.8	**62.236**	83.2	**62.184**
61.8	**62.356**	67.2	**62.321**	72.6	**62.281**	78.0	**62.234**	83.4	**62.182**
62.0	**62.355**	67.4	**62.320**	72.8	**62.279**	78.2	**62.233**	83.6	**62.180**
62.2	**62.353**	67.6	**62.318**	73.0	**62.278**	78.4	**62.231**	83.8	**62.178**
62.4	**62.352**	67.8	**62.317**	73.2	**62.276**	78.6	**62.229**	84.0	**62.176**
62.6	**62.351**	68.0	**62.316**	73.4	**62.274**	78.8	**62.227**	84.2	**62.174**
62.8	**62.350**	68.2	**62.314**	73.6	**62.273**	79.0	**62.225**	84.4	**62.172**
63.0	**62.349**	68.4	**62.313**	73.8	**62.271**	79.2	**62.223**	84.6	**62.170**
63.2	**62.347**	68.6	**62.311**	74.0	**62.269**	79.4	**62.222**	84.8	**62.168**
63.4	**62.346**	68.8	**62.310**	74.2	**62.268**	79.6	**62.220**	85.0	**62.166**
63.6	**62.345**	69.0	**62.308**	74.4	**62.266**	79.8	**62.218**	85.2	**62.164**
63.8	**62.344**	69.2	**62.307**	74.6	**62.264**	80.0	**62.216**	85.4	**62.162**
64.0	**62.343**	69.4	**62.305**	74.8	**62.263**	80.2	**62.214**	85.6	**62.160**
64.2	**62.341**	69.6	**62.304**	75.0	**62.261**	80.4	**62.212**	85.8	**62.158**
64.4	**62.340**	69.8	**62.302**	75.2	**62.259**	80.6	**62.210**	86.0	**62.155**
64.6	**62.338**	70.0	**62.301**	75.4	**62.258**	80.8	**62.208**	86.2	**62.153**
64.8	**62.337**	70.2	**62.299**	75.6	**62.256**	81.0	**62.206**	86.4	**62.151**
65.0	**62.336**	70.4	**62.298**	75.8	**62.254**	81.2	**62.204**	86.6	**62.149**
65.2	**62.335**	70.6	**62.296**	76.0	**62.252**	81.4	**62.202**	86.8	**62.147**

Cumulative Areas Under the Standard Normal Distribution

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998

Frequently Used Abbreviations

gals. = gallons
lbs. = pounds
cwt = hundredweight = 100 lbs.
w/c = water-cement ratio (weight basis)
ft^3 or cu. ft. = cubic feet
yd^3 or cu. yd. = cubic yard
SSD = saturated-surface dry
in. = inch
CA = coarse aggregate
FA = fine aggregate
min. = minimum
max. = maximum
psi. = pounds per square inch
sp. gr. = specific gravity
lbs./ft^3 = pounds per cubic foot
s/a = Sand Aggregate Ratio (FA to total aggregate) Volume Basis